Wattenberg Field Area, A Near Miss & Lessons Learned After 35 Years of Development History

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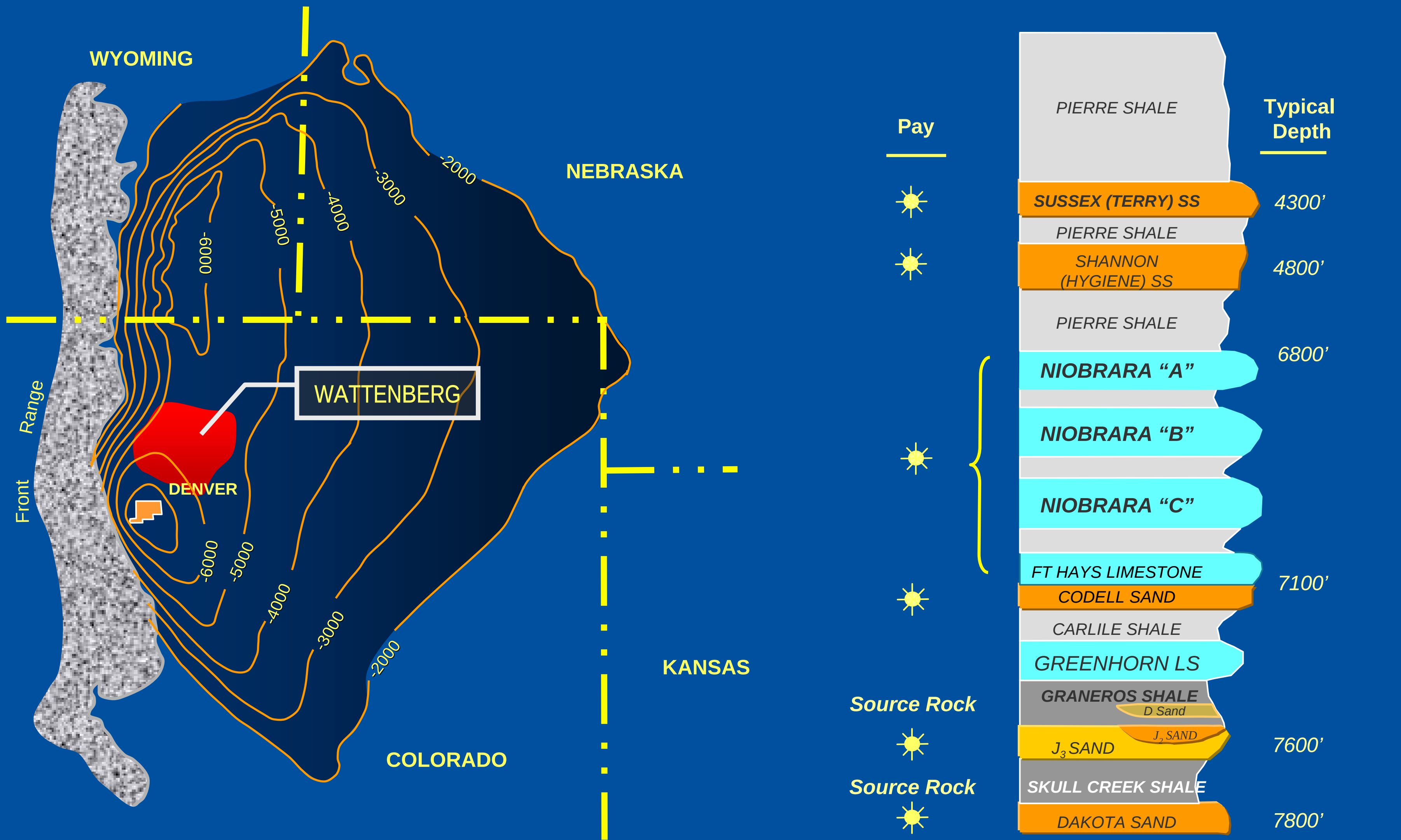
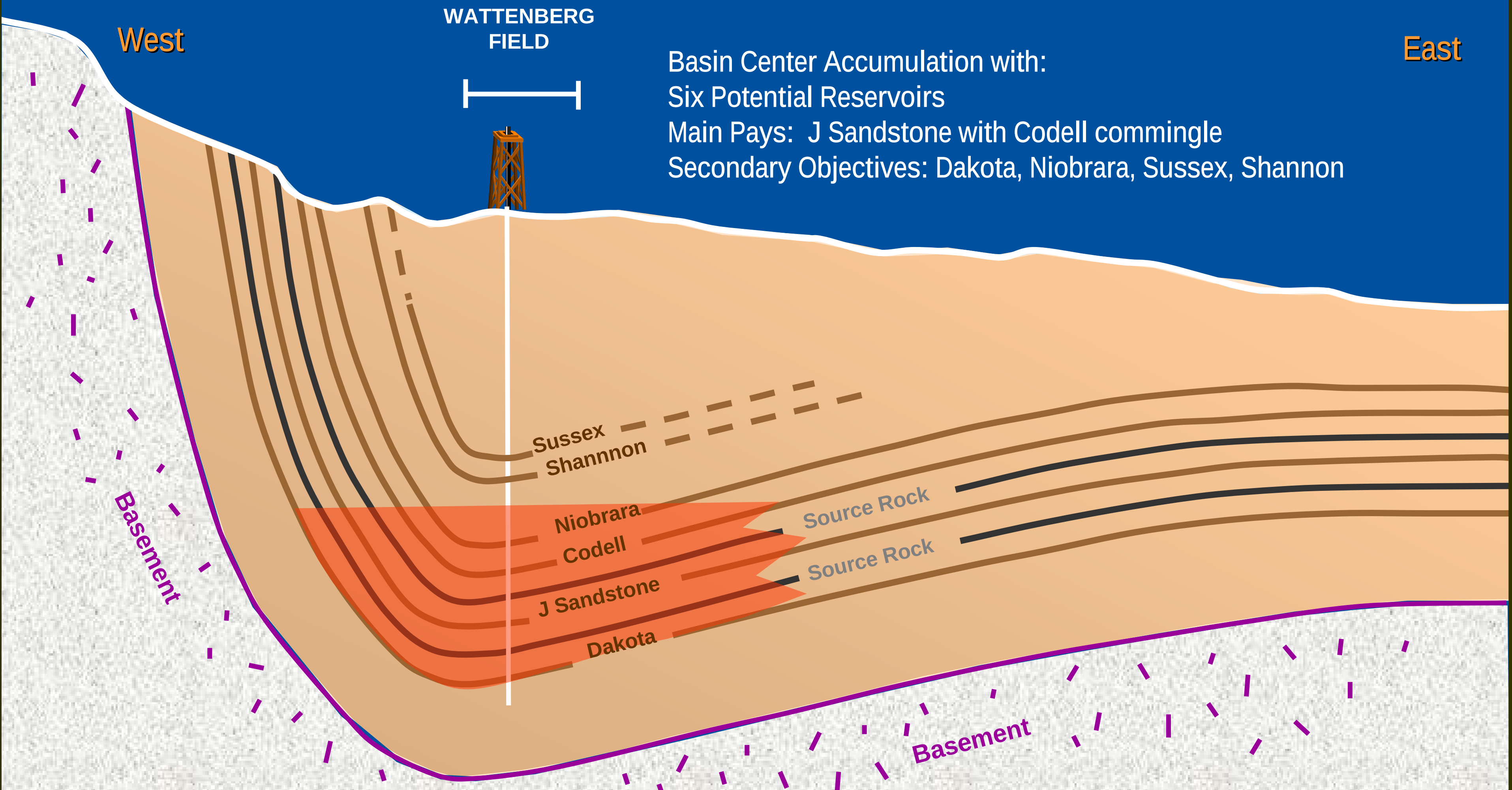
Robert J. Weimer

Wattenberg Field – DJ Basin



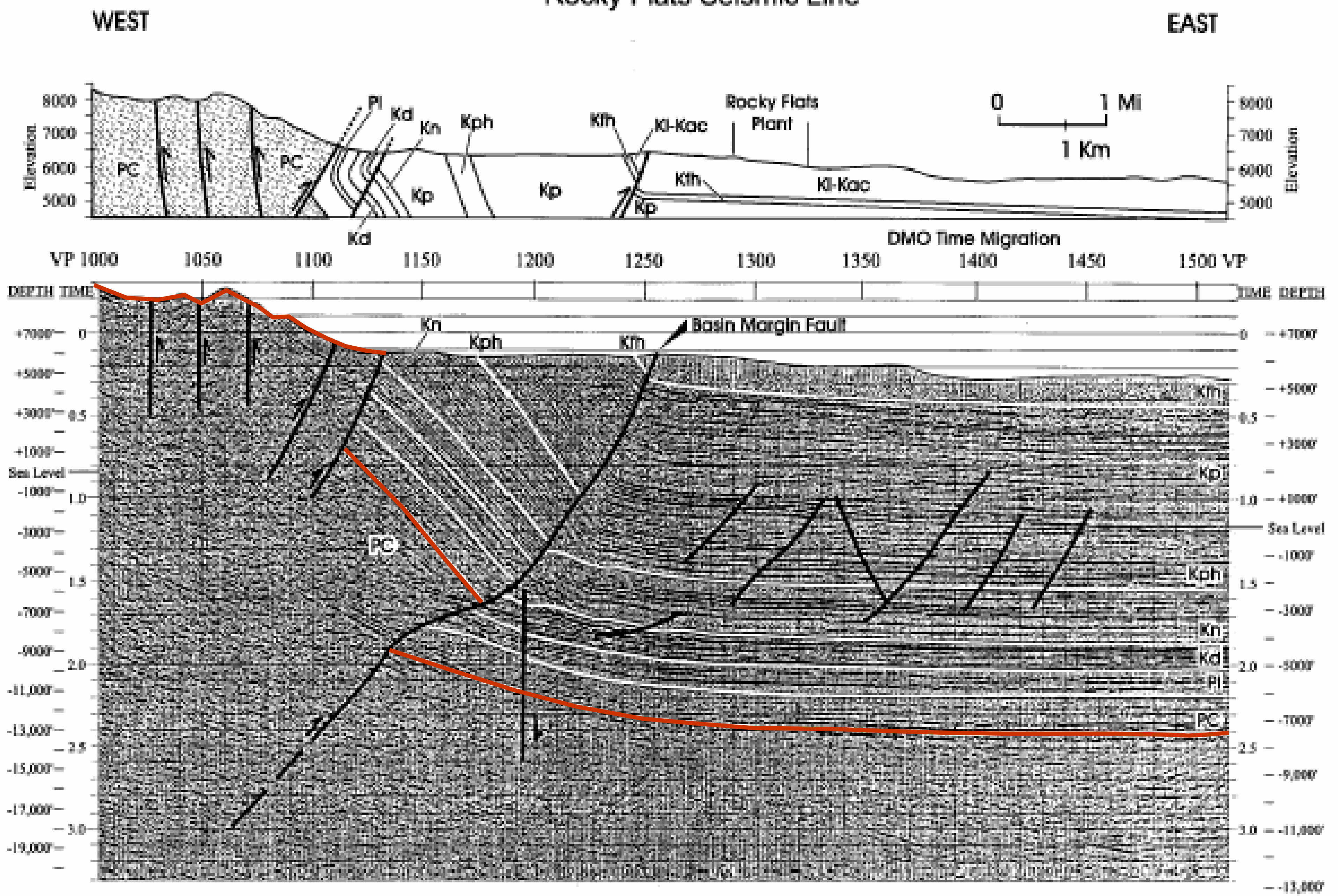
Sonnenberg, 2002

Diagrammatic Cross-Section
Denver Basin



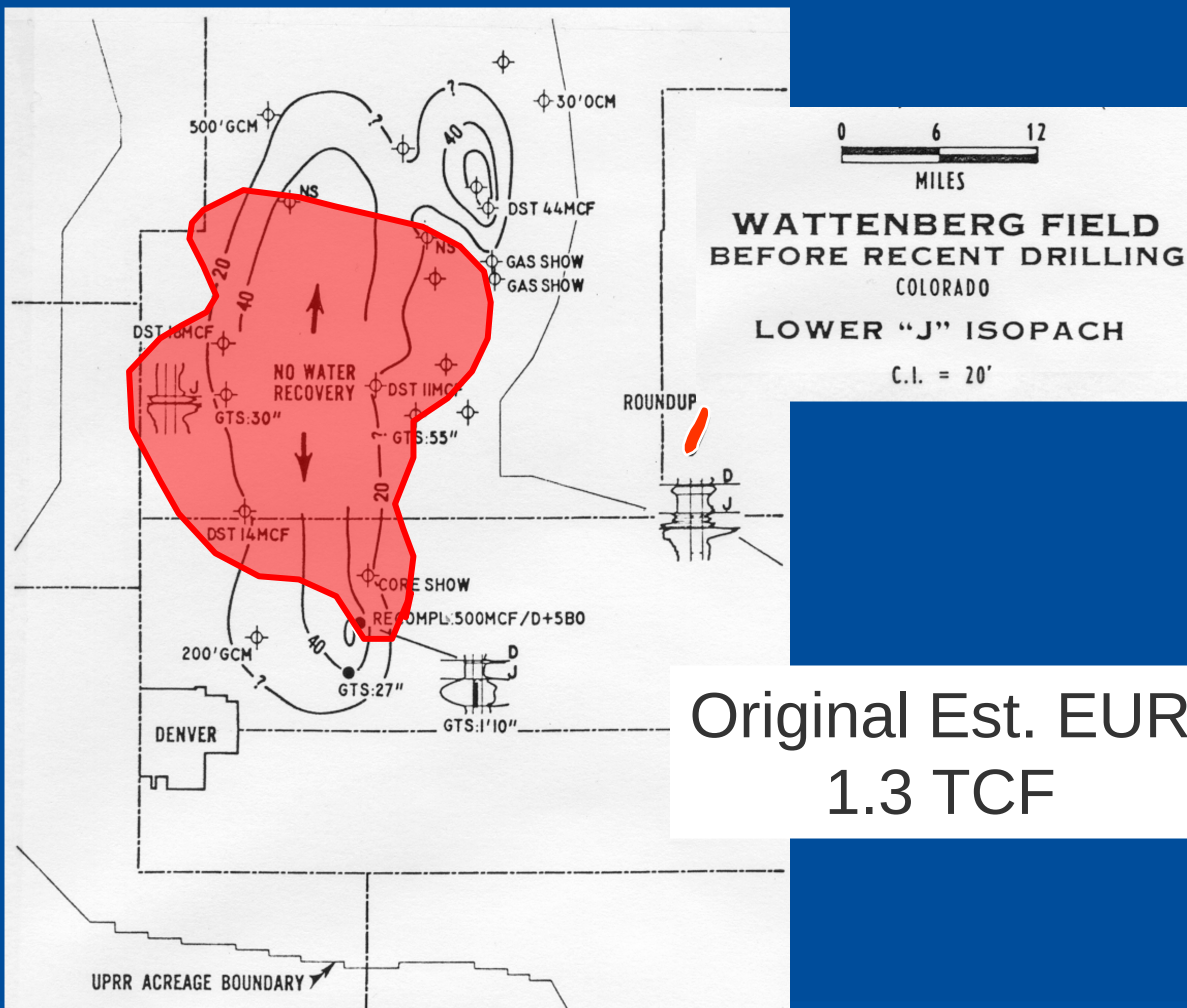
Gustason and Sonnenberg, 2003

Rocky Flats Seismic Line



Weimer & Ray, 1997

History of Wattenberg Gas Field



Original Est. EUR
1.3 TCF

A Near Miss!

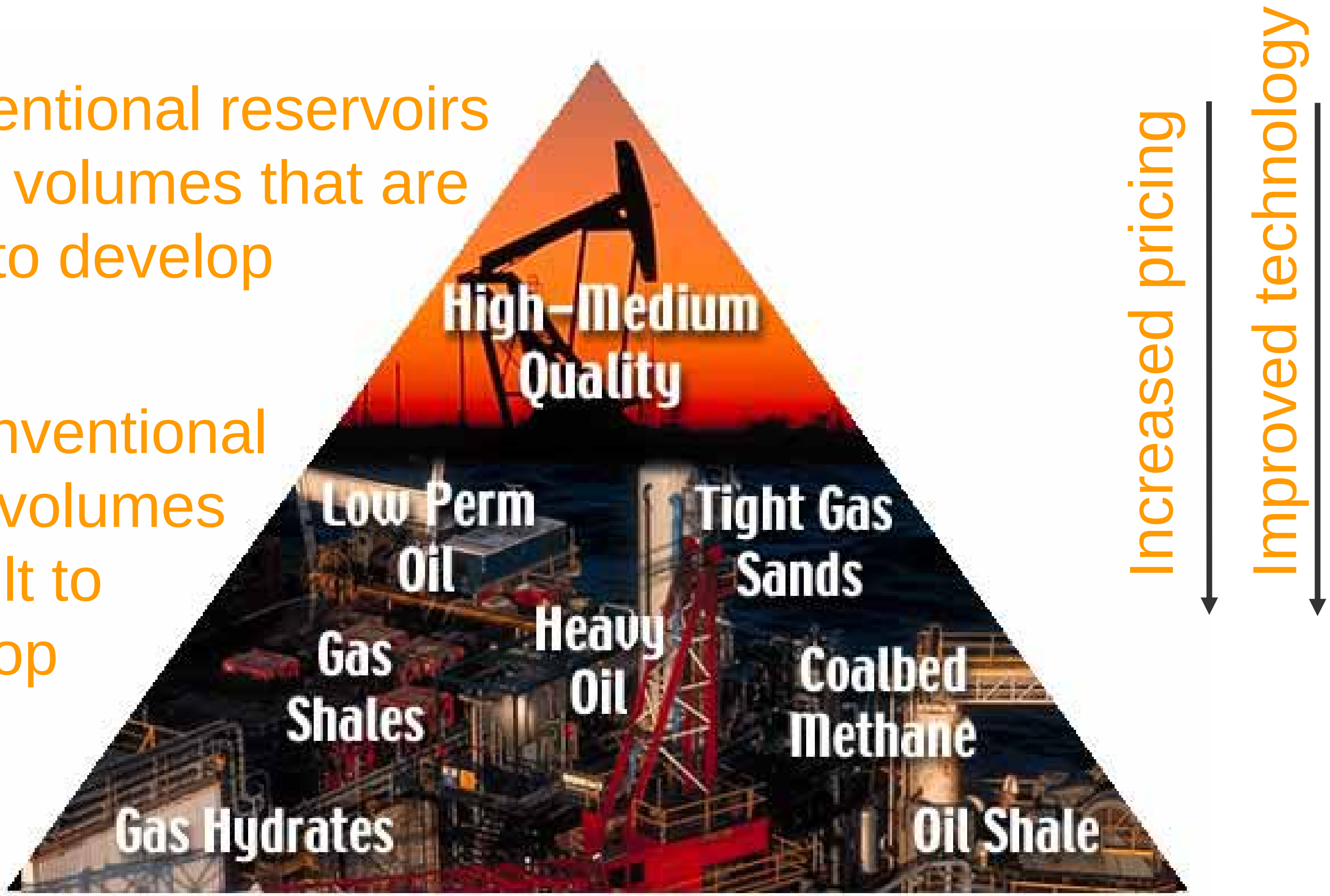
- All DSTs or cores taken in the J indicated shows of gas
- Core analyses of the J compared with those of the Dakota in the SJB
- Old wells in area remarkably similar
- Earlier discovery at Roundup - 1967
- Wattenberg discovered - 1970

Matuszczak, 1973

Conventional & Unconventional Reservoirs & The Resource Triangle

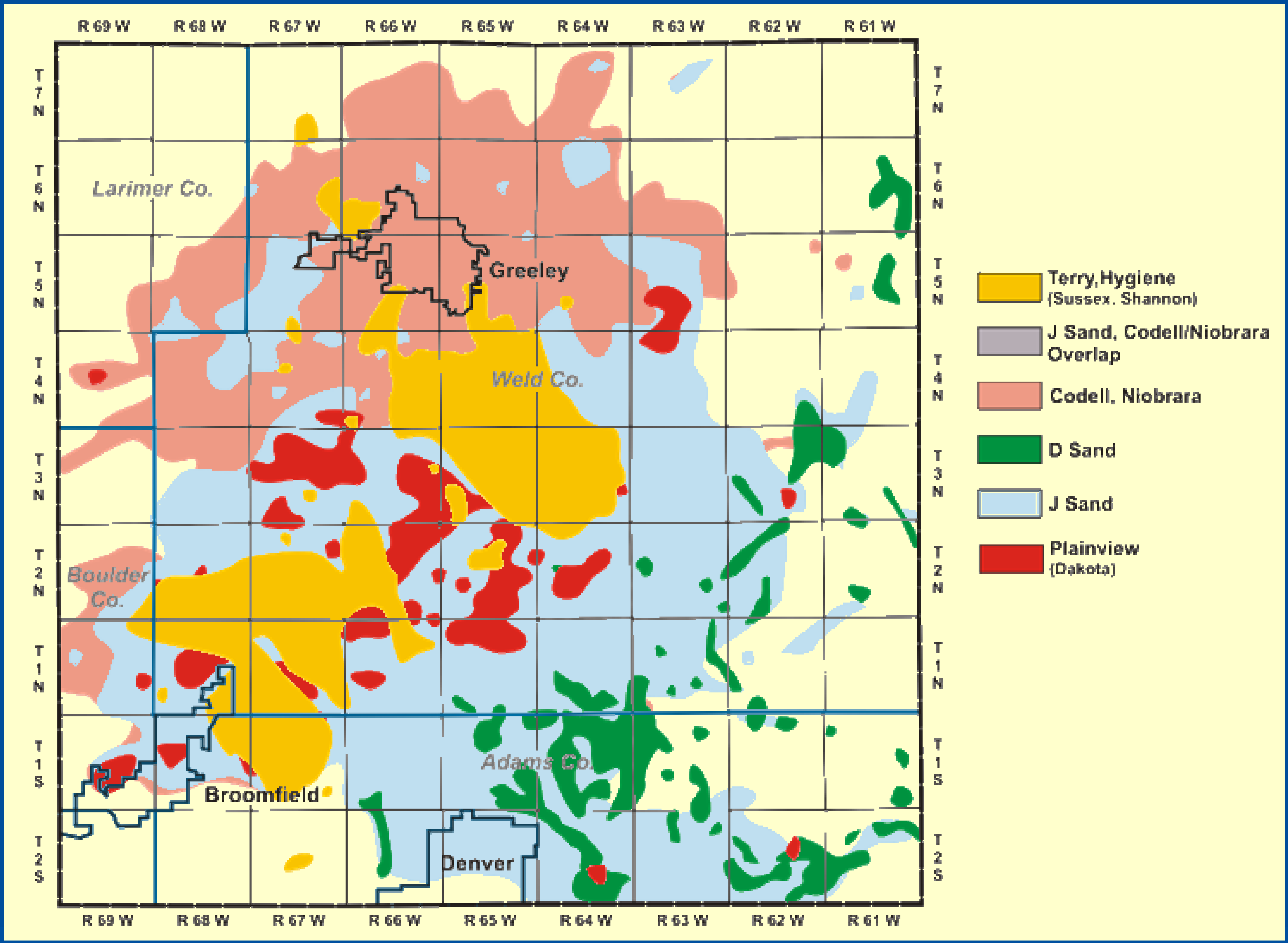
Conventional reservoirs
Small volumes that are easy to develop

Unconventional large volumes difficult to develop

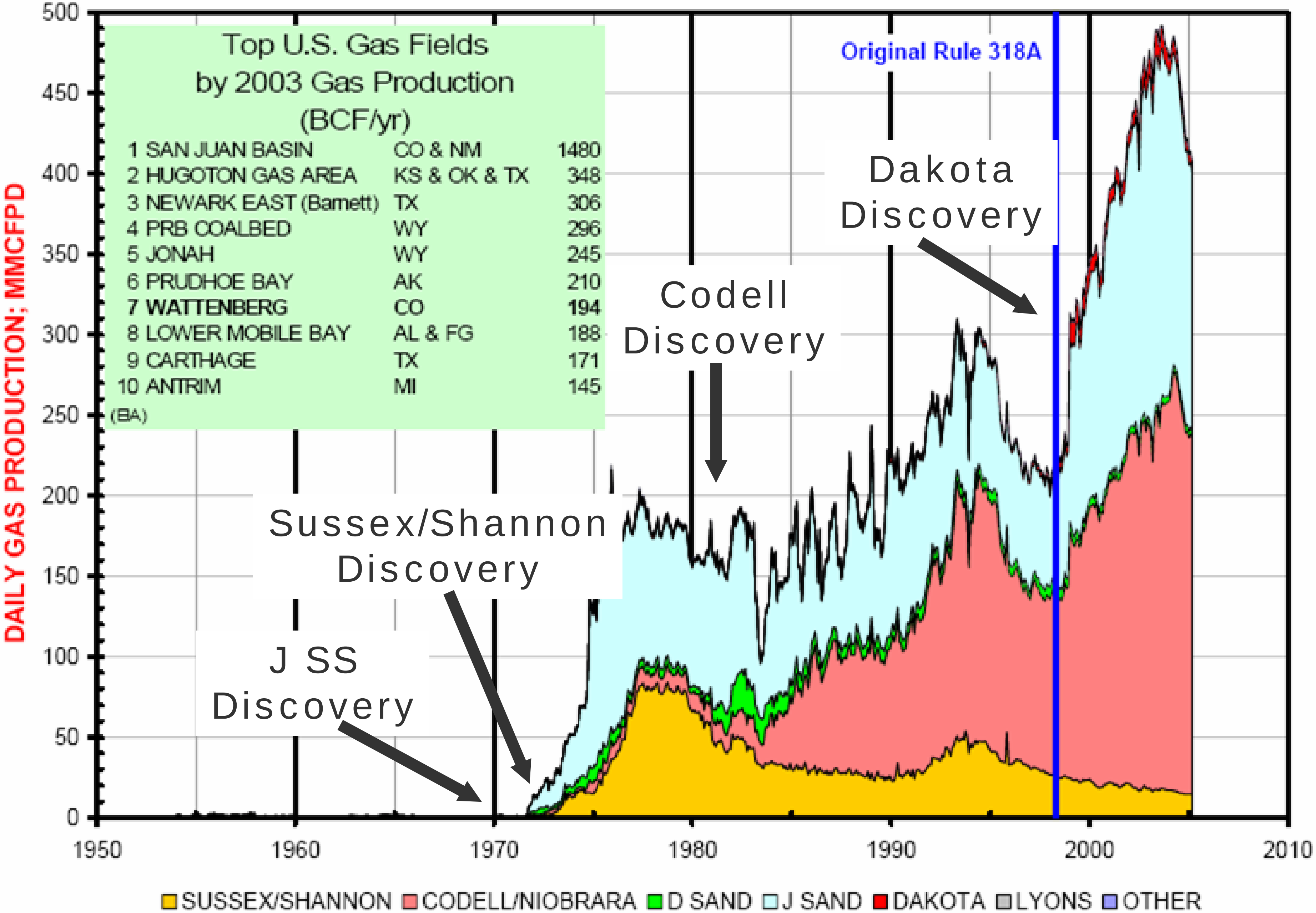


Holditch, 2005

Currently Productive Areas-GWA



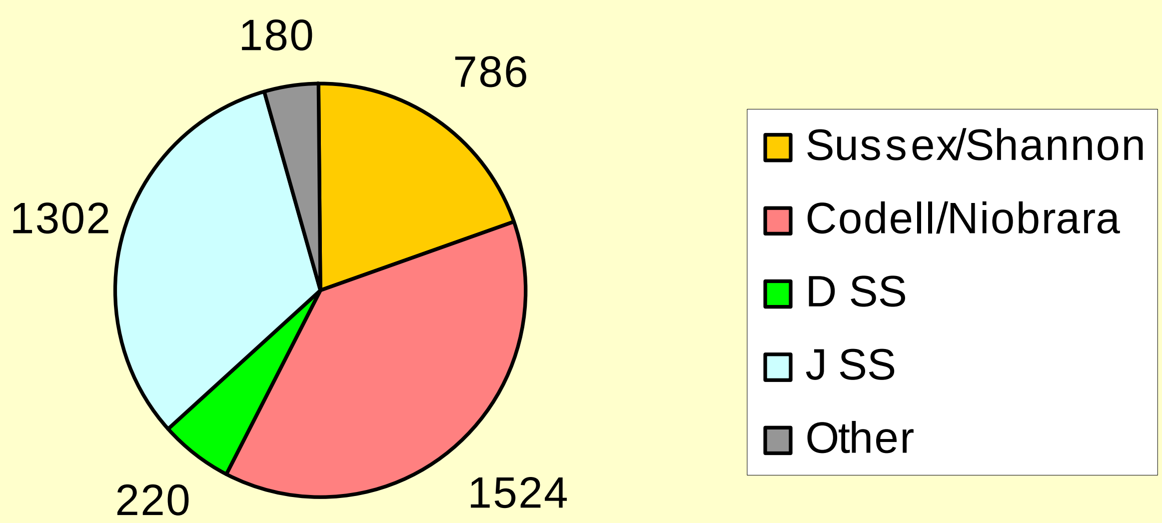
Wright, 2005; Modified after Ladd, 2001



Top U.S. Gas Fields
by 2003 Gas Production
(BCF/yr)
1 SAN JUAN BASIN CO & NM 1480
2 HUGOTON GAS AREA KS & OK & TX 348
3 NEWARK EAST (Barnett) TX 306
4 PRB COALBED WY 296
5 JONAH WY 245
6 PRUDHOE BAY AK 210
7 WATTENBERG CO 194
8 LOWER MOBILE BAY AL & FG 188
9 CARTHAGE TX 171
10 ANTRIM MI 145
(BA)
Original Rule 318A
Dakota Discovery
Codell Discovery
Sussex/Shannon Discovery
J SS Discovery
DAILY GAS PRODUCTION; MMCFPD
500
450
400
350
300
250
200
150
100
50
0
1950
1960
1970
1980
1990
2000
2010
SUSSEX/SHANNON
CODELL/NIOBRARA
D SAND
J SAND
DAKOTA
LYONS
OTHER

Wright, 2005

Cumulative Production GWA



Cum: 4012 BCFe (34%)

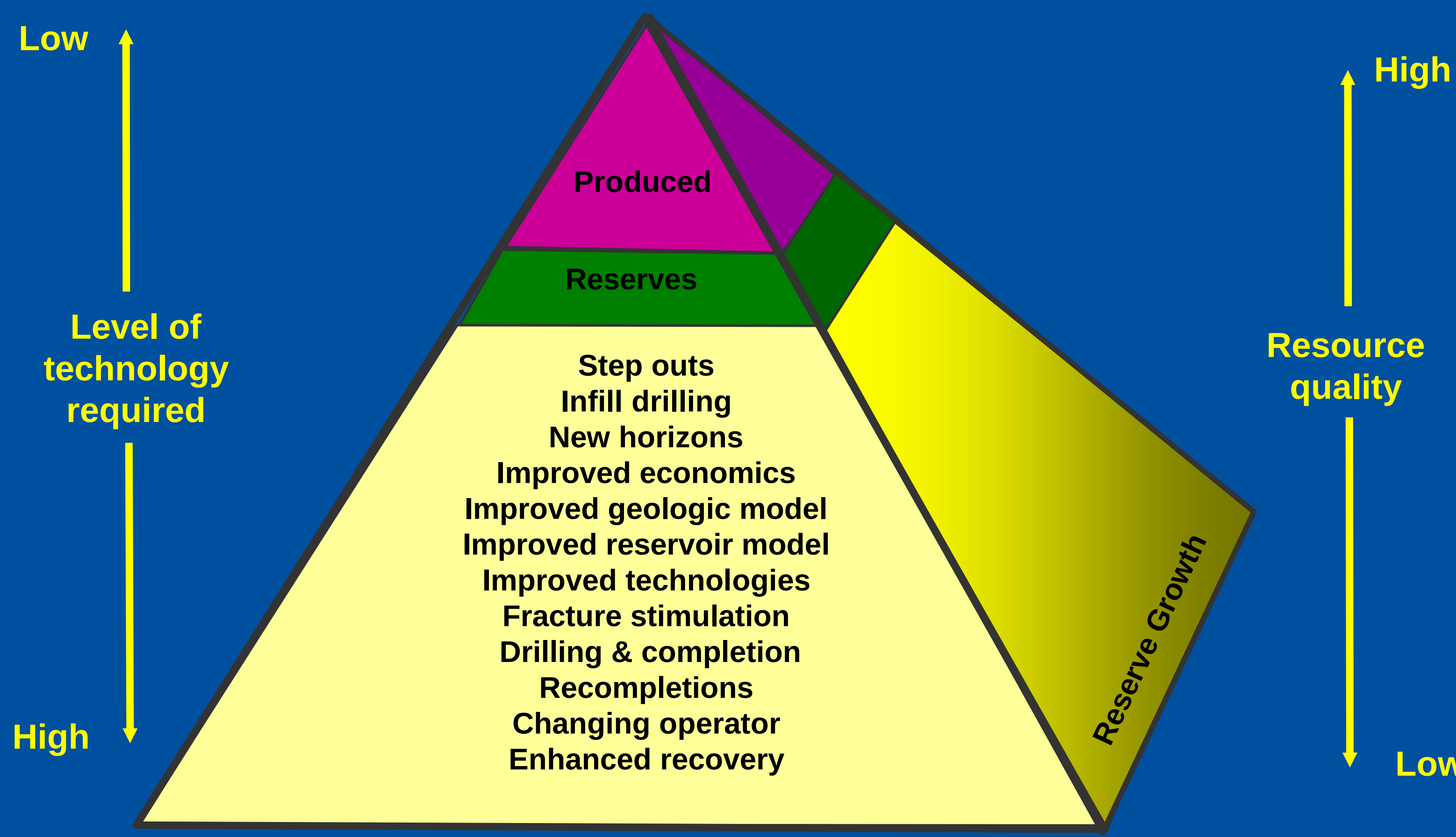
Modified from Wright, 2005

GWA Spacing History

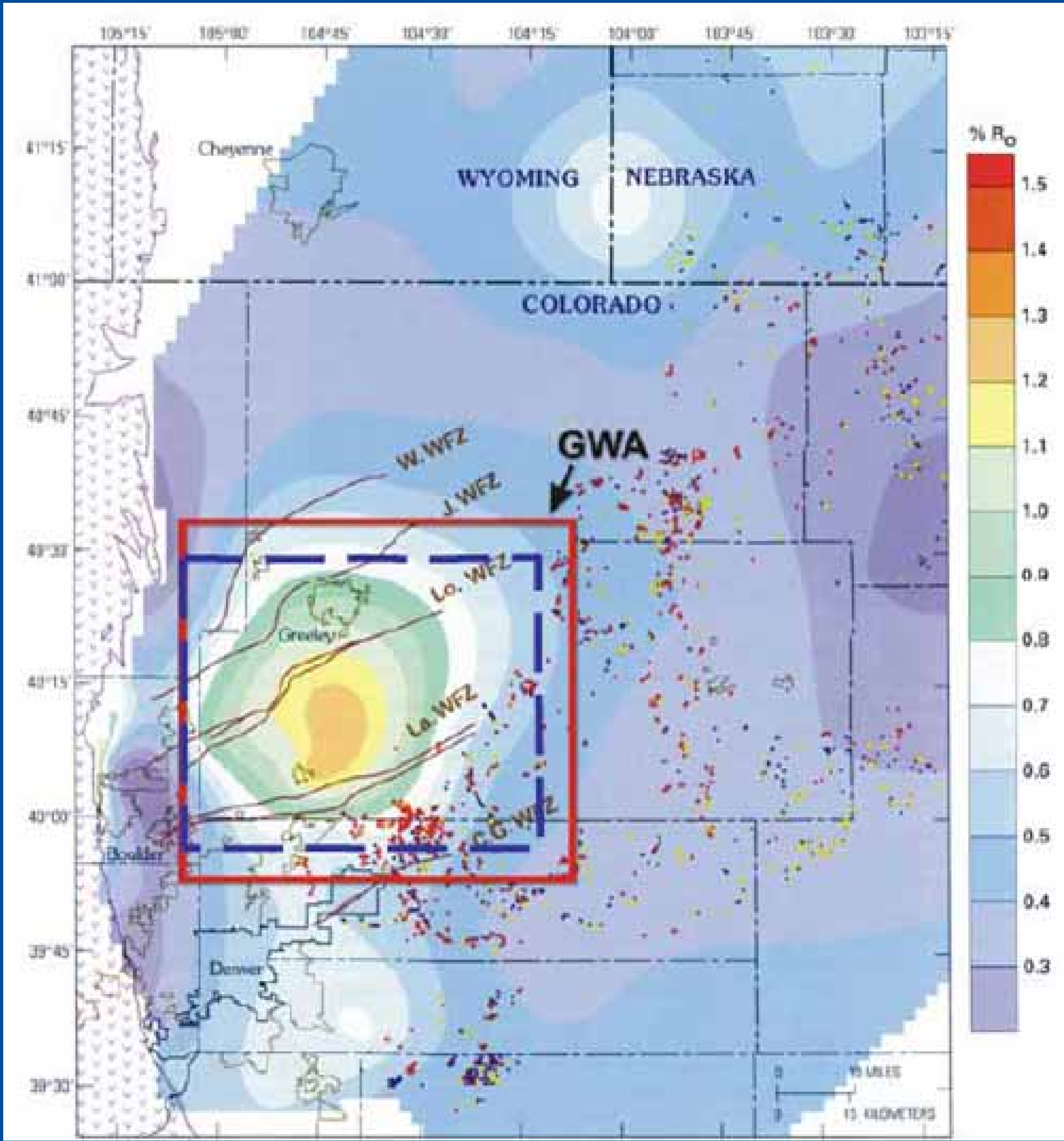
- 1970: 320 acre units for drilling & spacing of J Sand
- 1979: Additional J Sand well allowed per 320 acre unit
- 1980: Section 29 tax credit; Tight gas sand designation (exp. 2002)
- 1983: Codell spaced on 80 acre
- 1984,85: Niobrara added to Codell spacing order
- 1991: J Sand wells can be recompleted to C-N & commingling of all downhole zones allowed
- 1998: Rule 318A allows 5 wells per quarter section in GWA for all Cretaceous age formations (81 townships)
- 2005: Rule 318A modified to allow for section line & quarter section line wells (~ 20 acre spacing 27 townships)

Modified from Wright, 2005 & Weimer, 2005

Oil & Gas Field Growth



Sonnenberg, 04



The Wattenberg Geothermal Anomaly

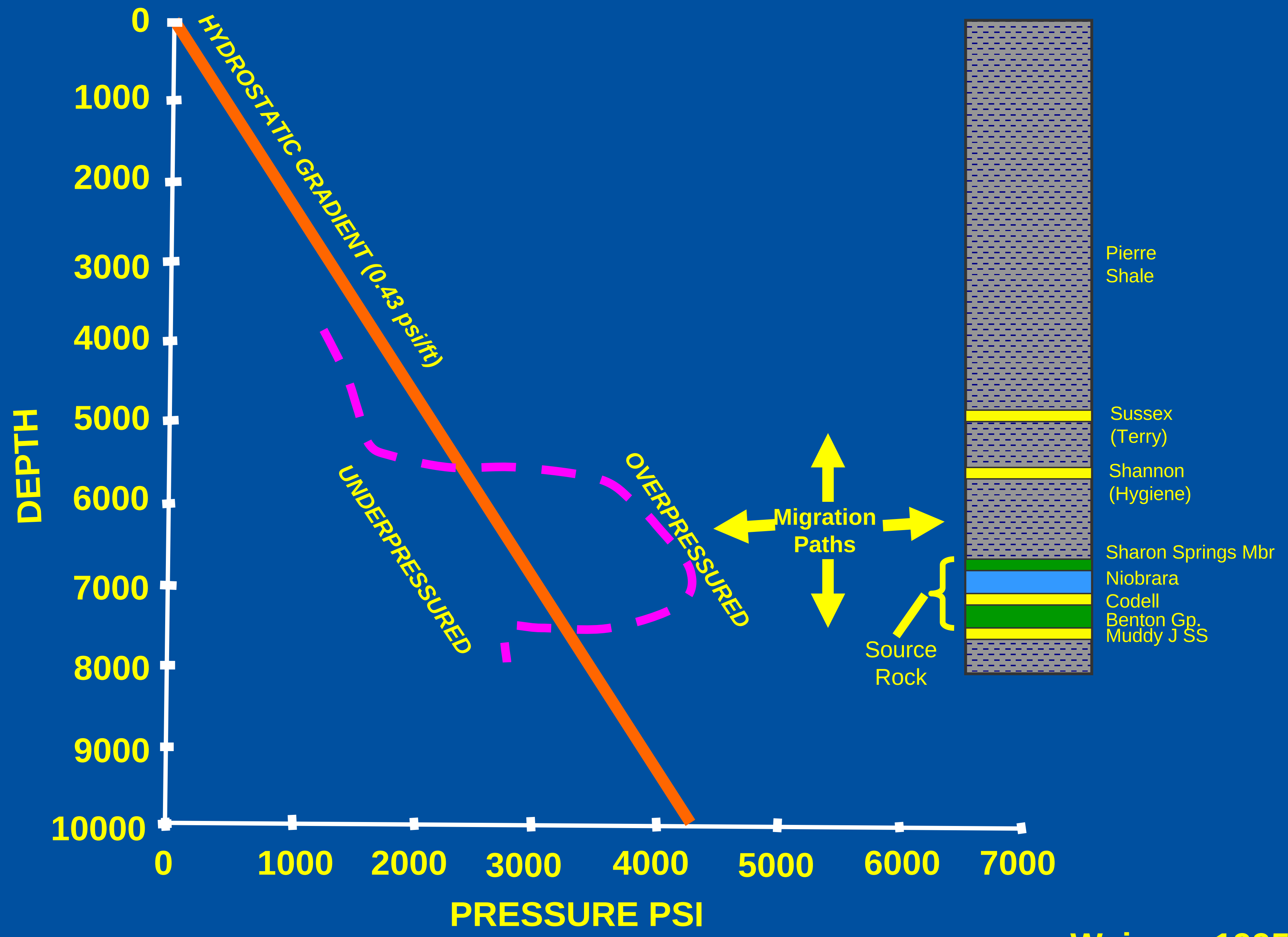
Vitrinite Reflectance Values, %Ro

Higley & Cox, 2005

Wattenberg Thermal Anomaly

- Related to igneous masses in basement
- Located where CMD intersects Denver Basin
- Direct temperature measurements in wells
- Ro values
- GORs

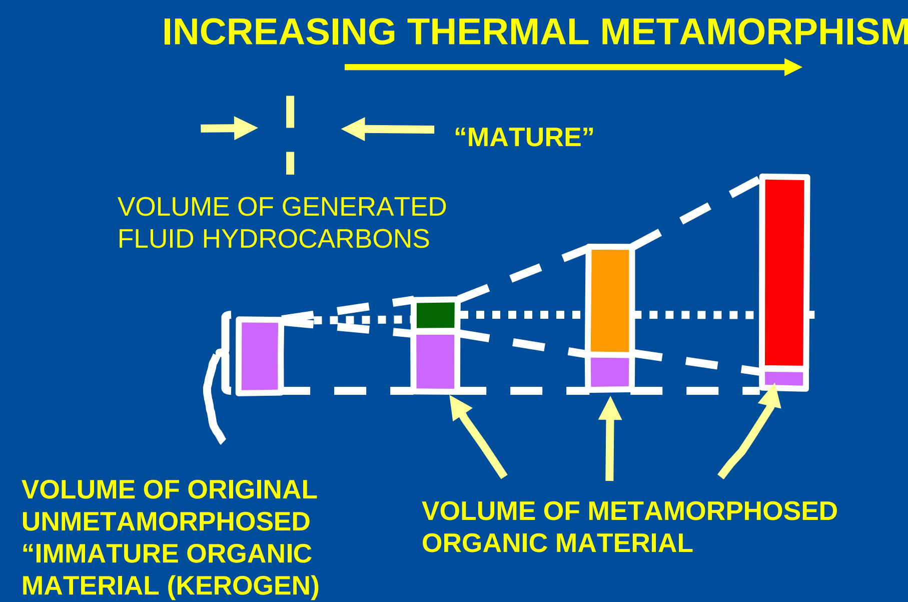
Modified from Weimer, 1995



DEPTH
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE PSI
0
1000
2000
3000
4000
5000
6000
7000
HYDROSTATIC GRADIENT (0.43 psi/ft)
UNDERPRESSURED
OVERPRESSURED
Migration
Paths
Source
Rock
Pierre
Shale
Sussex
(Terry)
Shannon
(Hygiene)
Sharon Springs Mbr
Niobrara
Codell
Benton Gp.
Muddy J SS

Weimer, 1995

Overpressuring in Rockies Basins



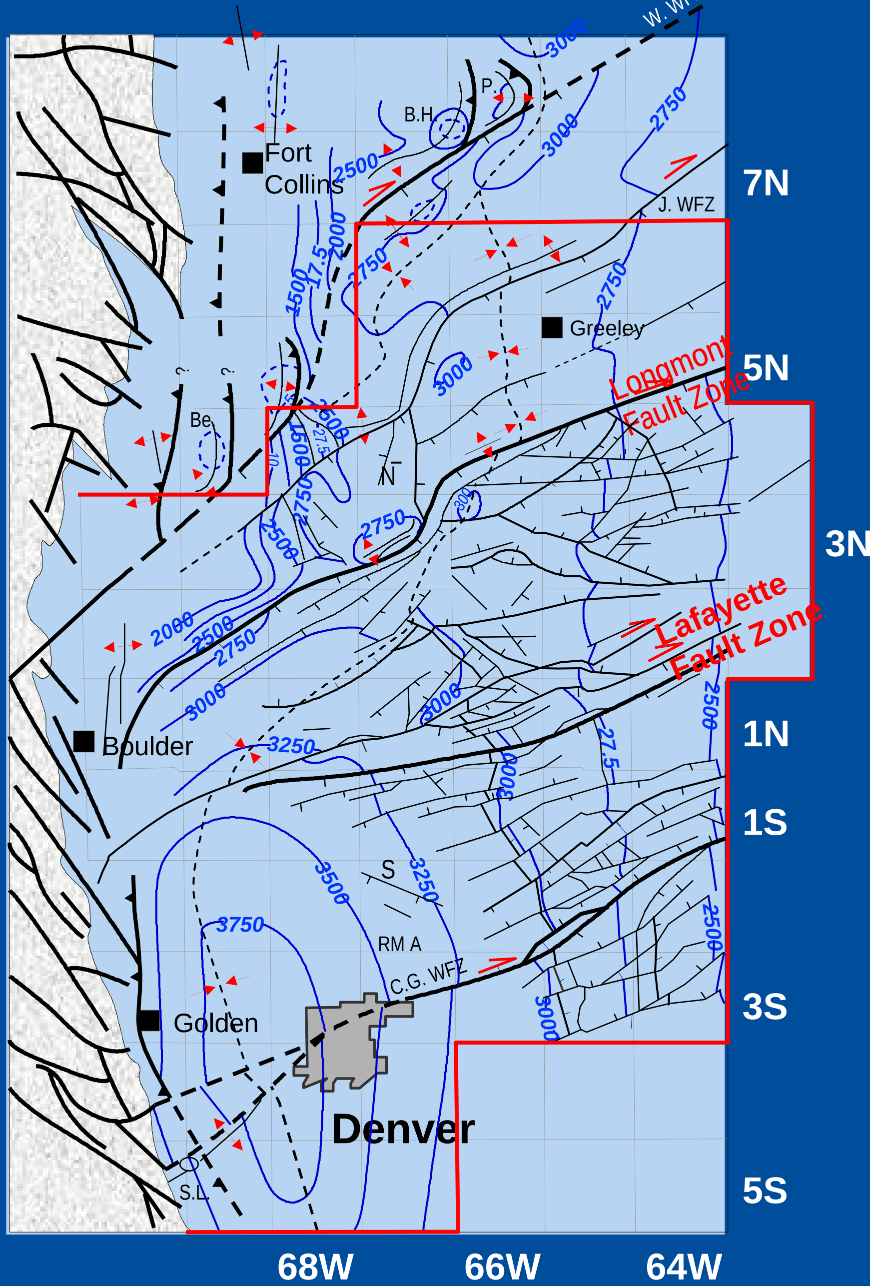
ASSUMES GENERATED HYDROCARBONS ARE RETAINED IN SYSTEM & CONVERT TO STABLE SPECIES

SAS, 04

Modified from Spencer, 1987 and Meissner, 1980

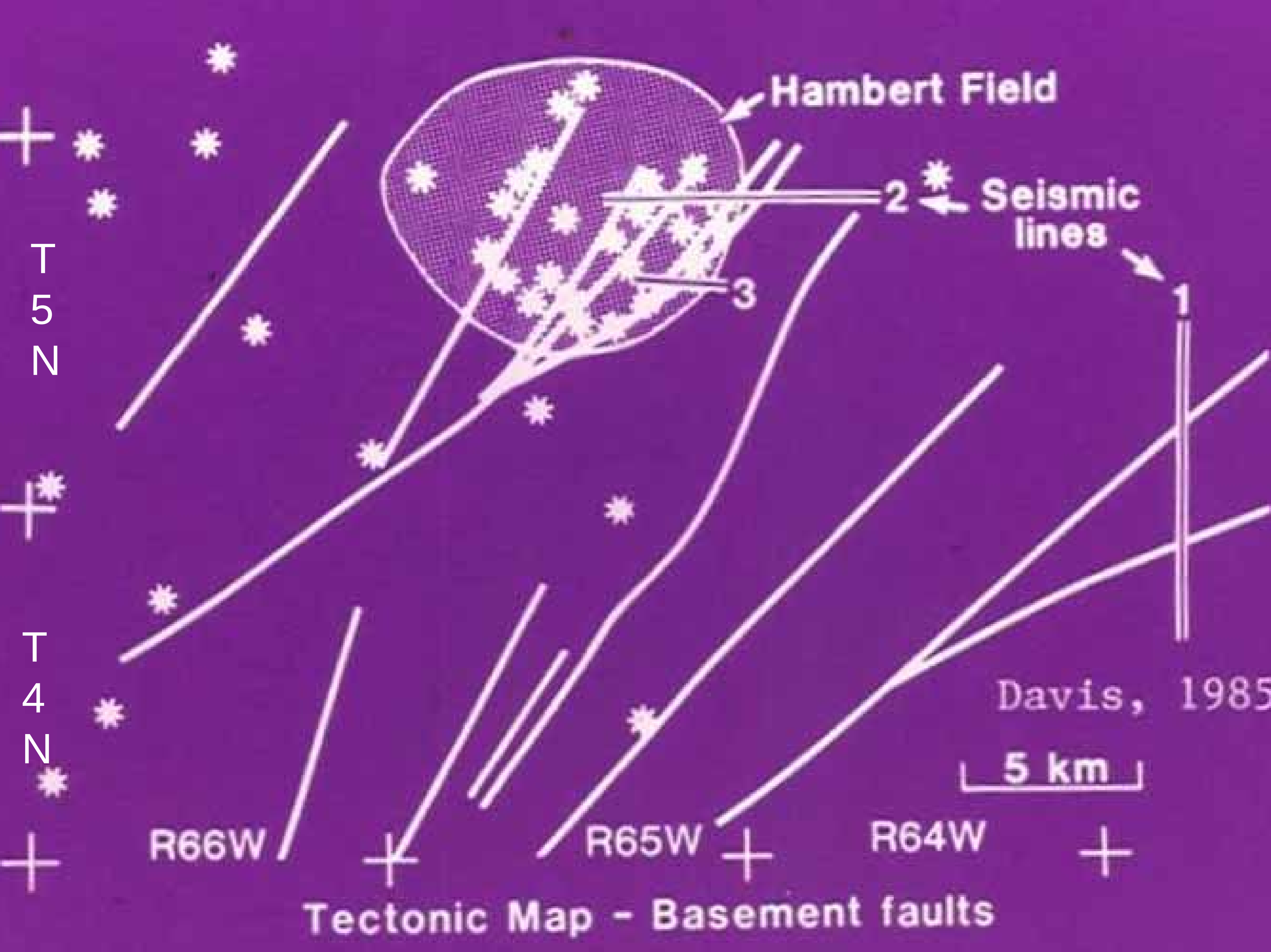
Structural Overview

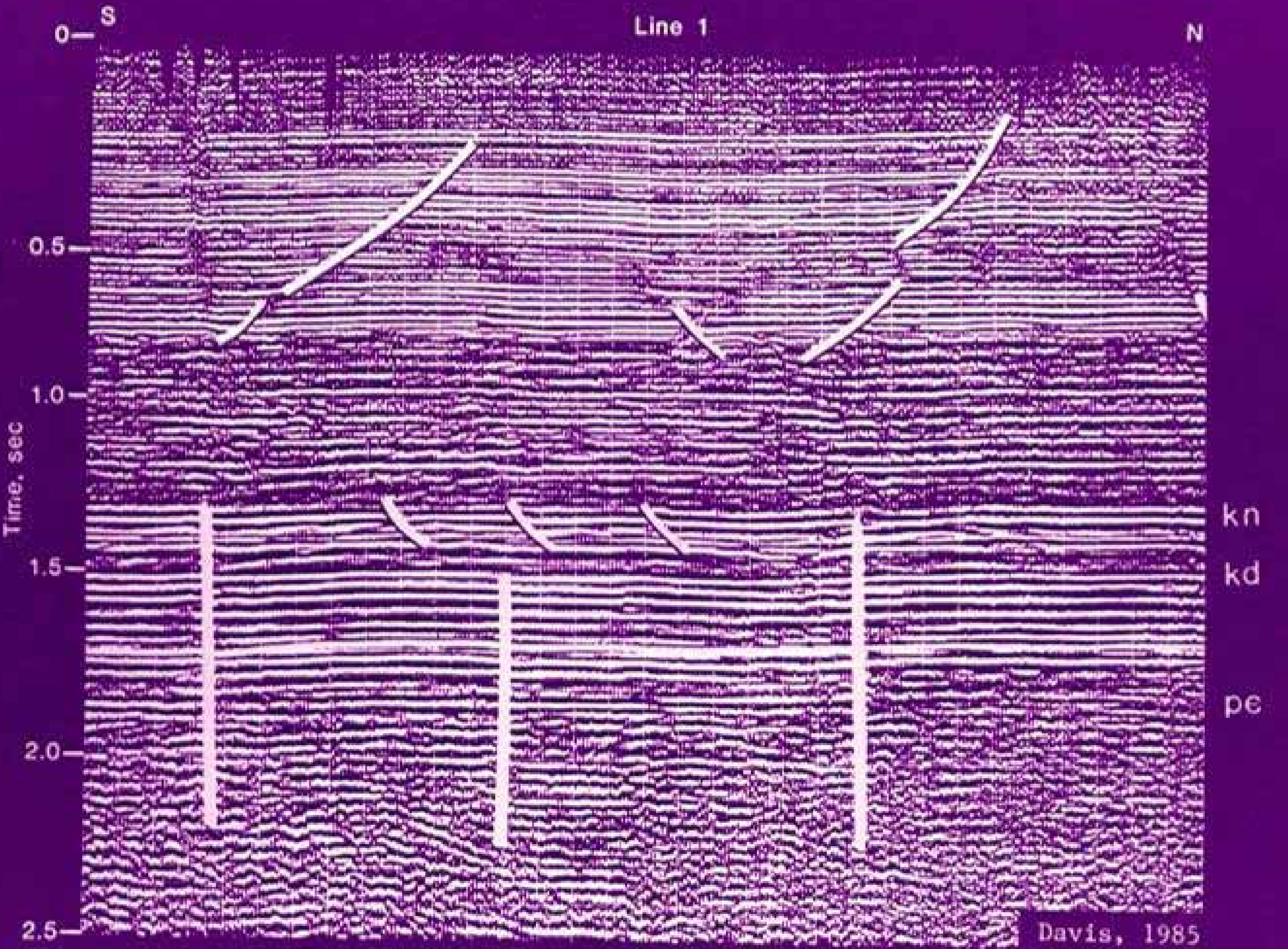
- North-trending structural axis
- Northeast trending right lateral wrench faults
- Antithetic and synthetic horsts and grabens



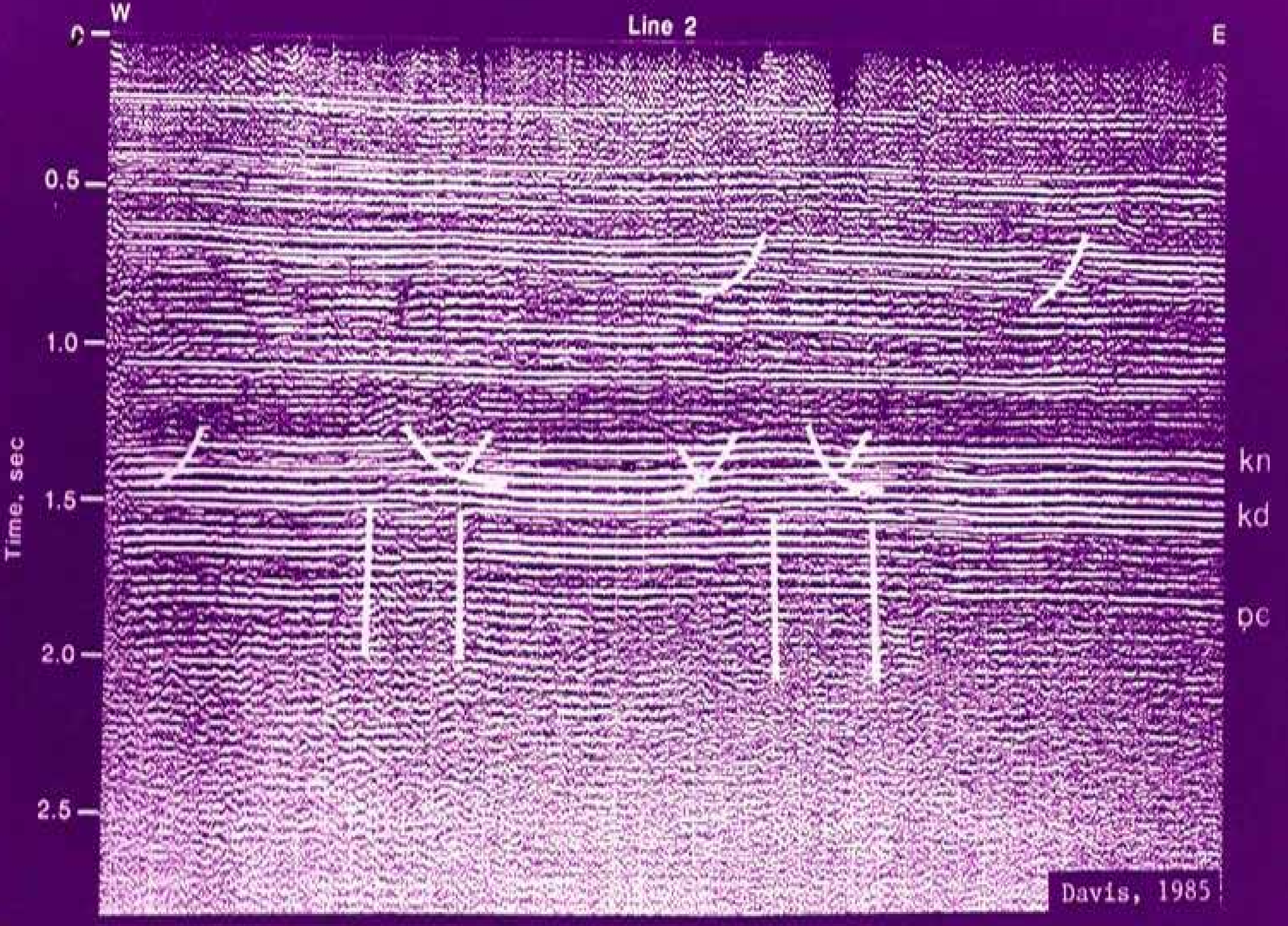
Contours represent subsea depths to top J SS

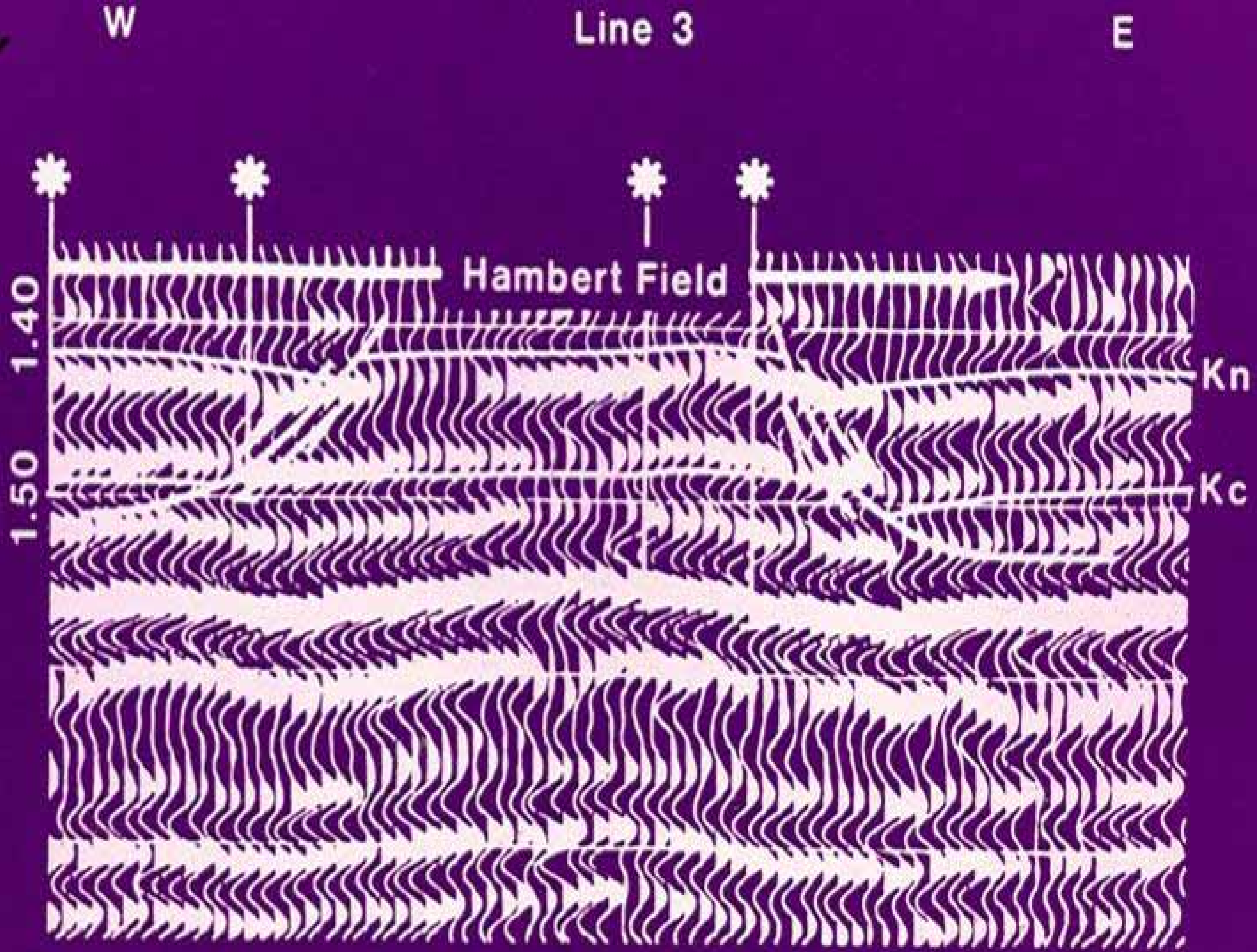
Weimer, 2000


Hambert Field
2
3
Seismic
lines
1
T
5
N
T
4
N
Davis, 1985
5 km
R66W
R65W
R64W
Tectonic Map - Basement faults

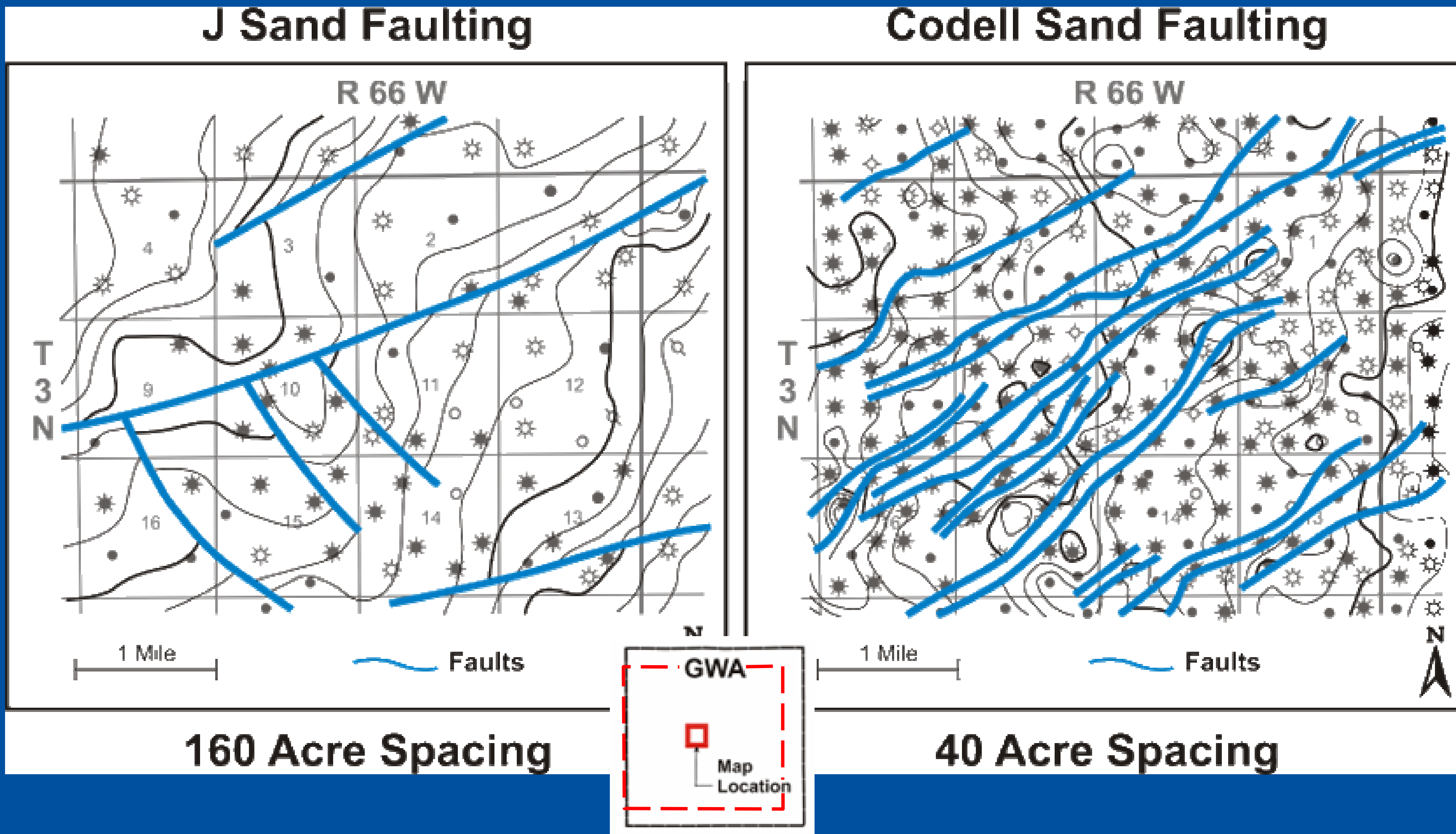


S
Line 1
N
0
0.5
1.0
1.5
2.0
2.5
Time, sec
kn
kd
pc
Davis, 1985


W
Line 2
E
0
0.5
1.0
1.5
2.0
2.5
Time, sec
kn
kd
pc
Davis, 1985

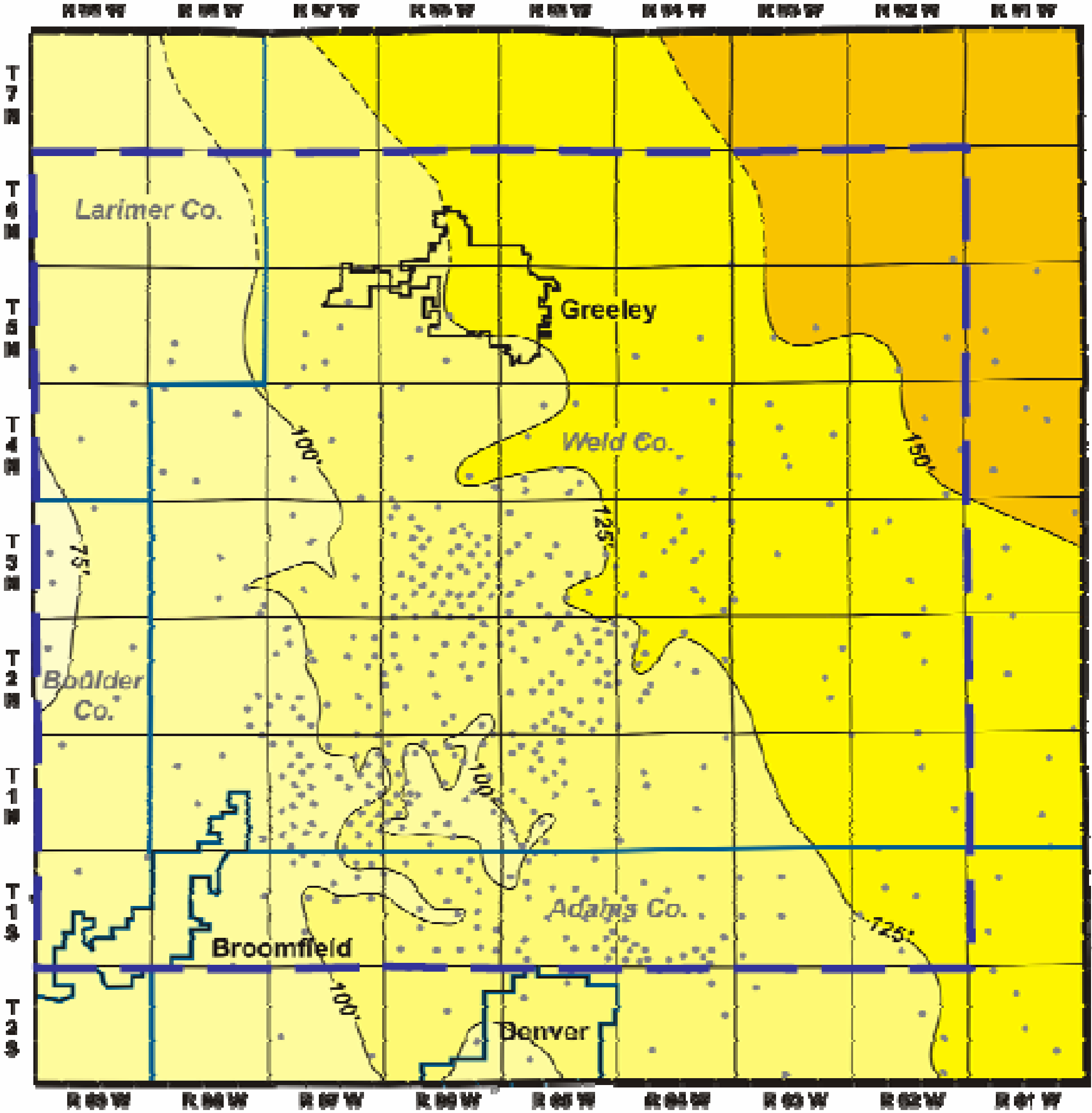

W
Line 3
E
Hambert Field
1.40
1.50
Kn
Kc

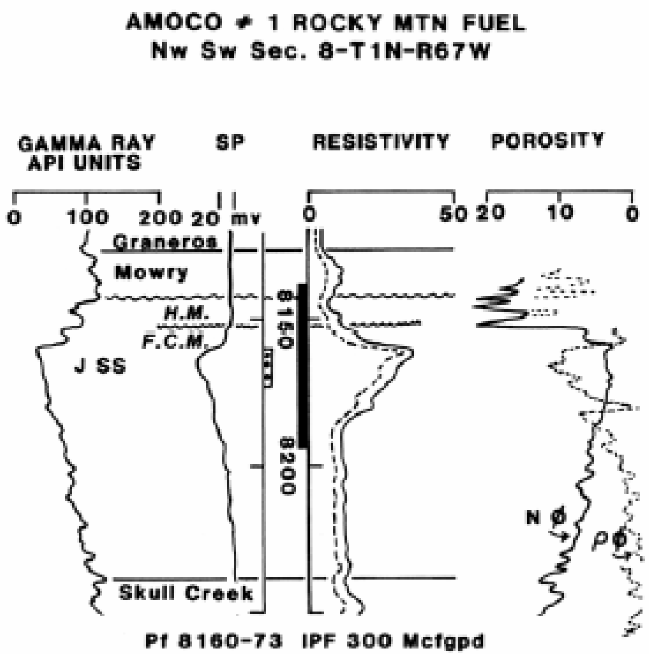
Codell Faulting Density is Greater than J Sand



Ladd, 2001

Isopach Map of J Sand

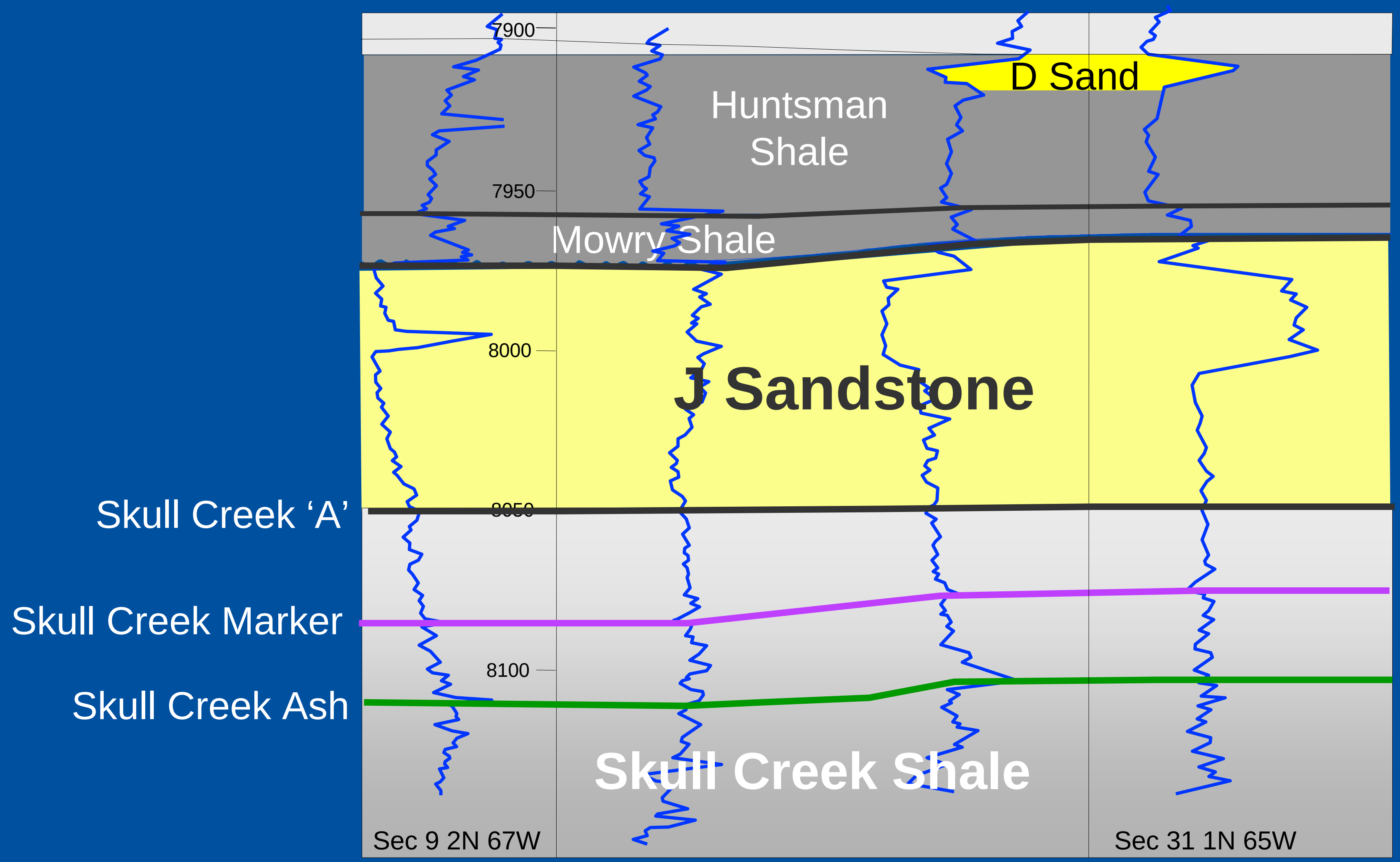




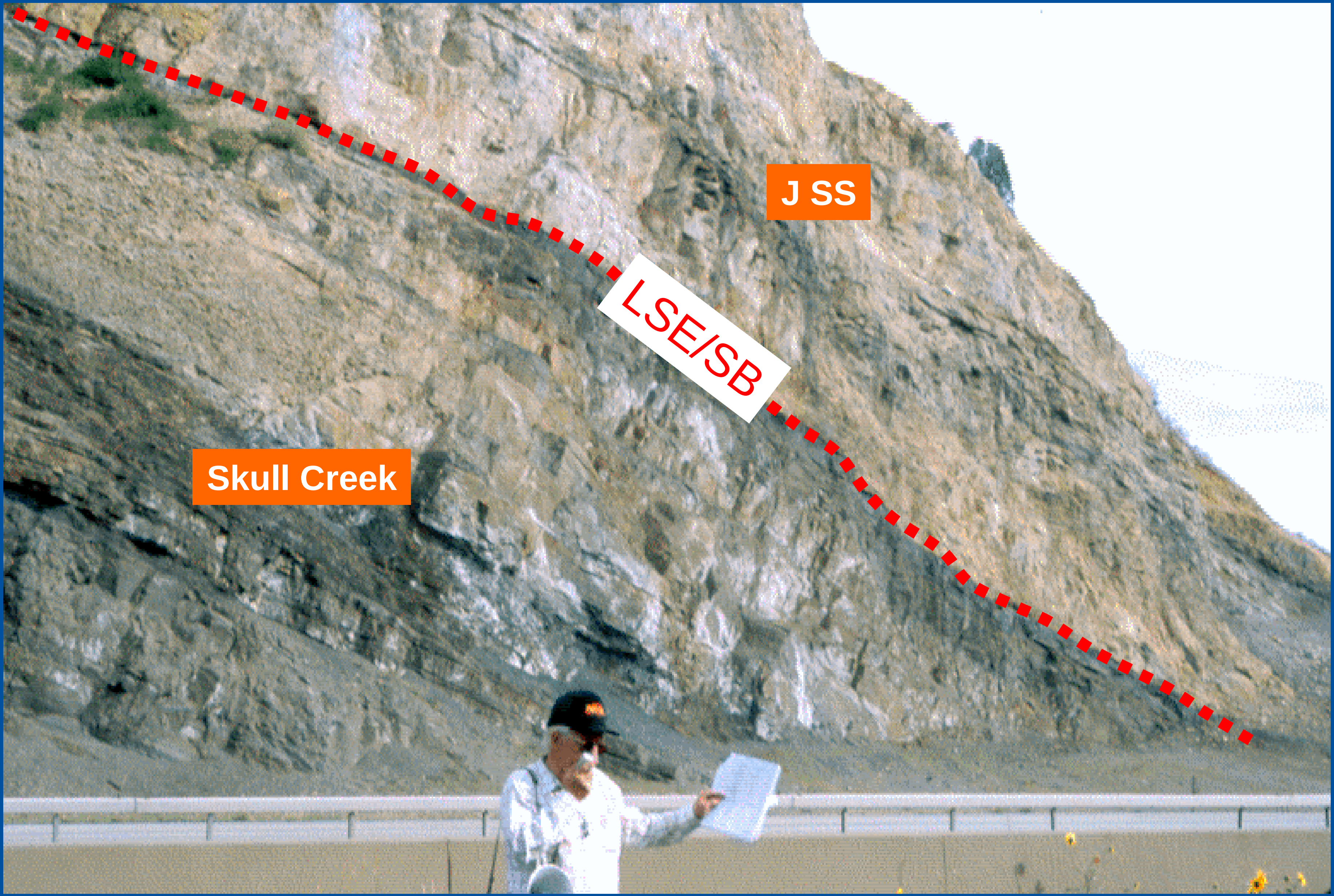
GWA

Weimer & Sonnenberg, 1989

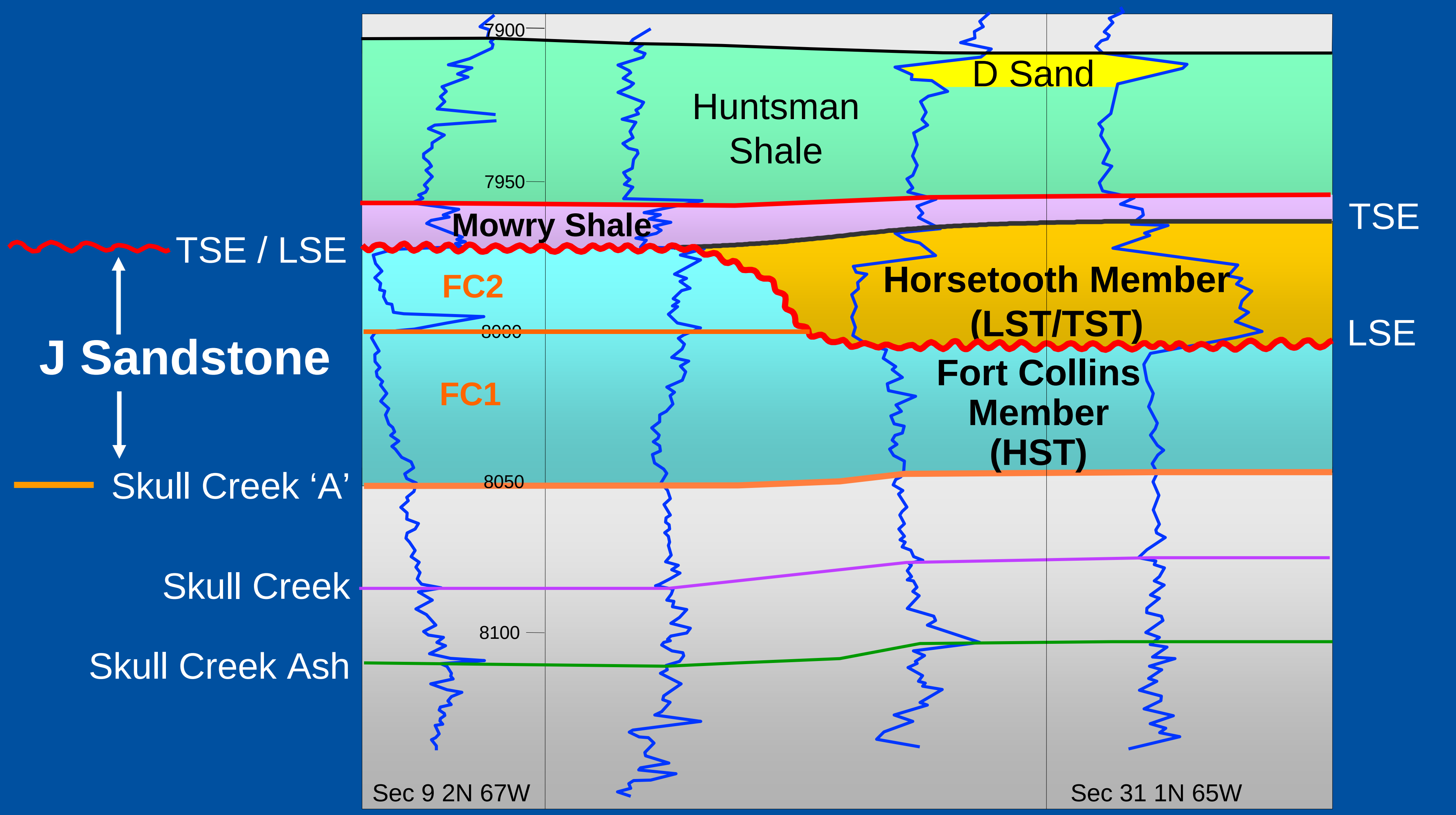
J Sandstone Stratigraphic Nomenclature



Gustason and Sonnenberg, 2003

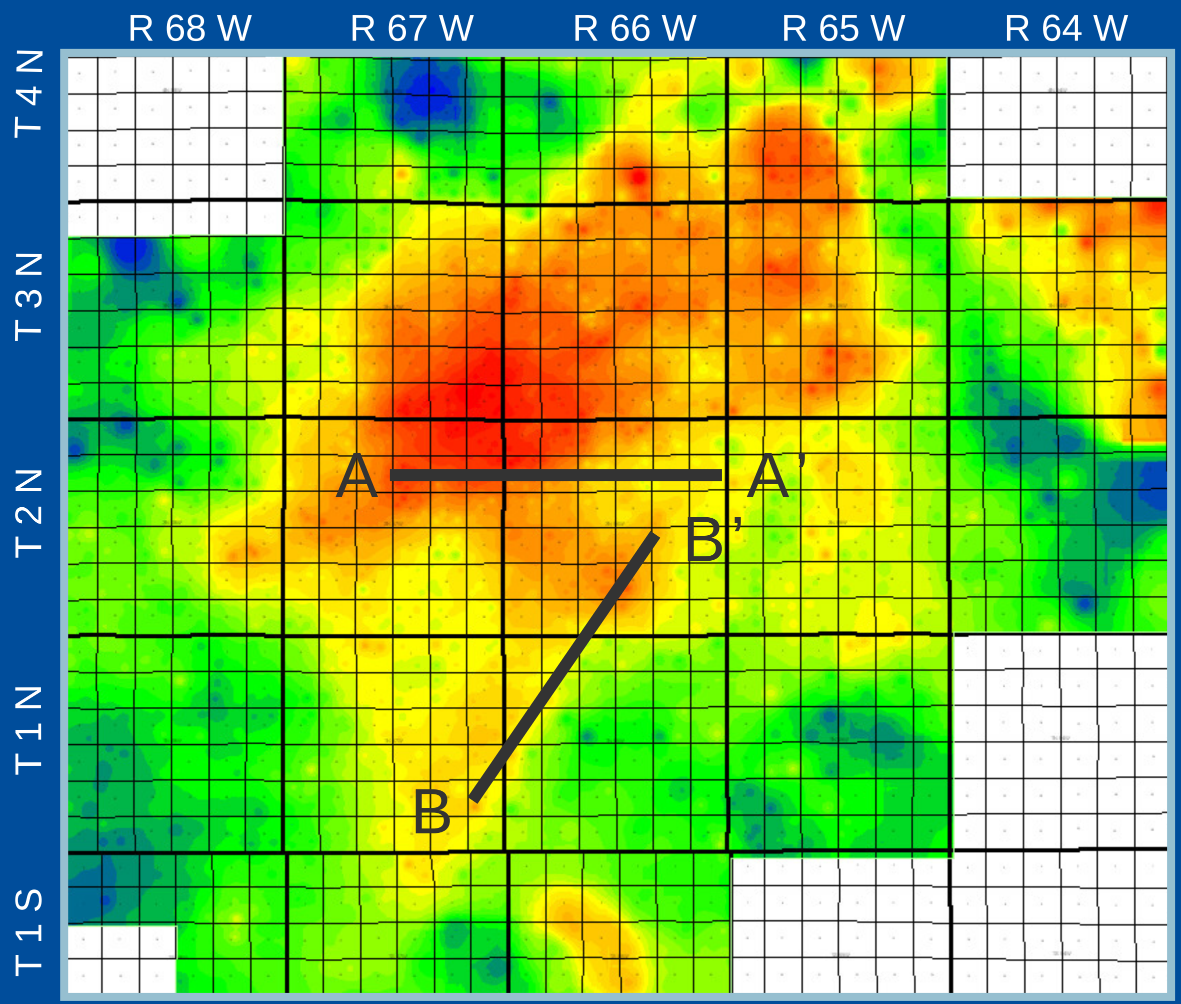

J SS
LSE/SB
Skull Creek

Sequence Stratigraphy of J Sandstone



Gustason and Sonnenberg, 2003

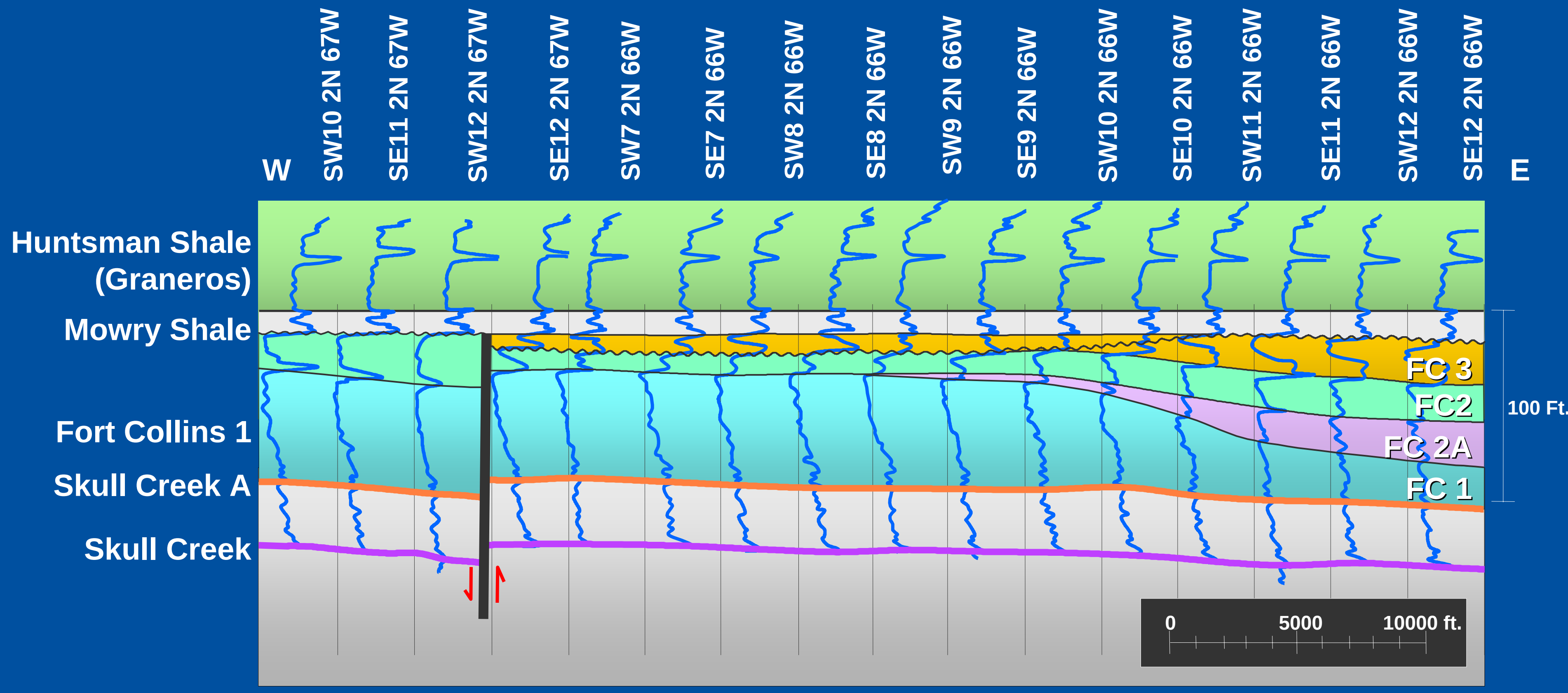
J Sandstone
Original Gas in Place



EUR
Red > 15 Bcf / sec.
Green 10 - 12 Bcf / sec.
Blue < 8 Bcf / sec.

Hu, 2002

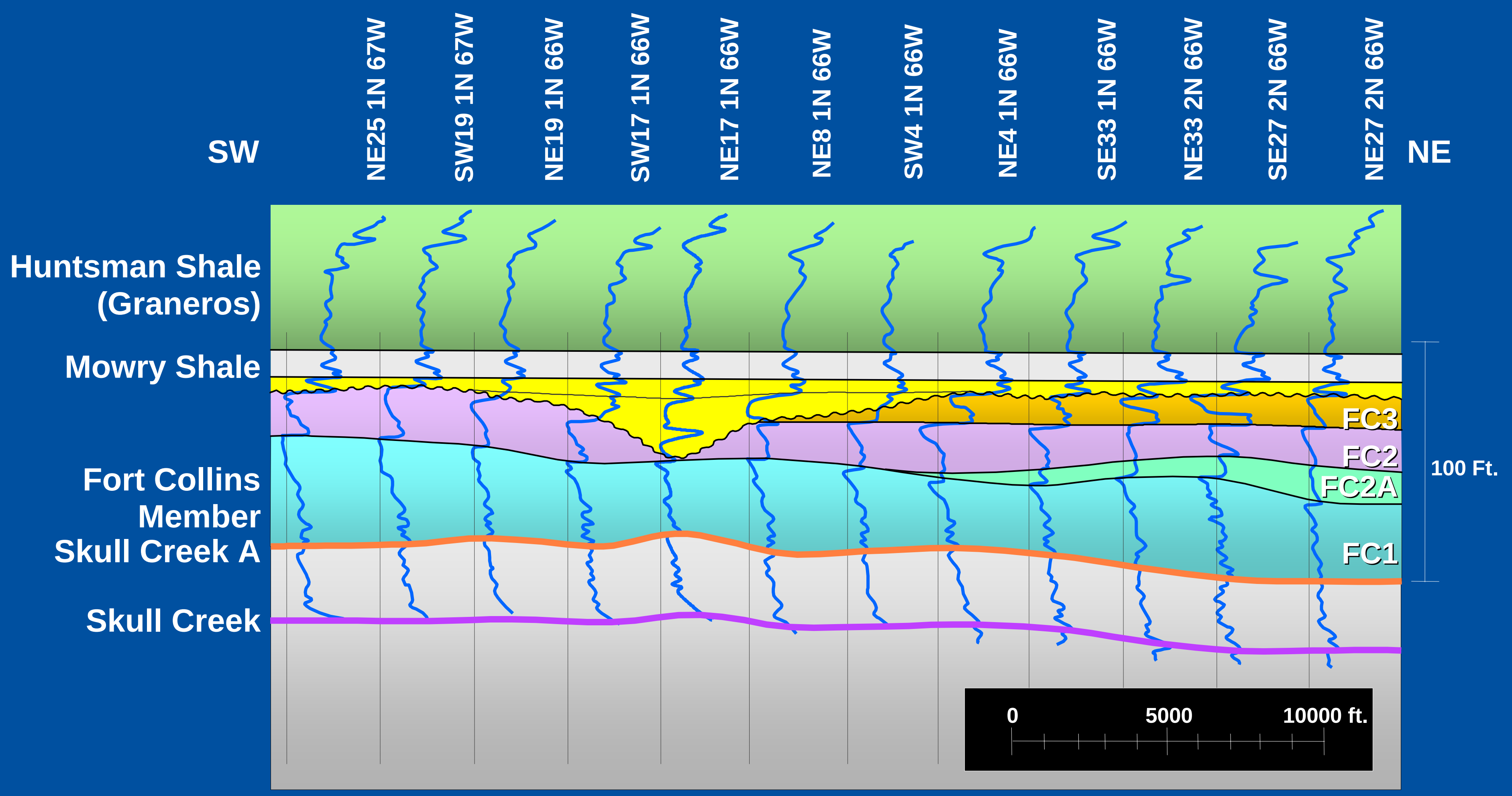
Sequence Stratigraphy of Fort Collins Member



Gustason and Sonnenberg, 2003

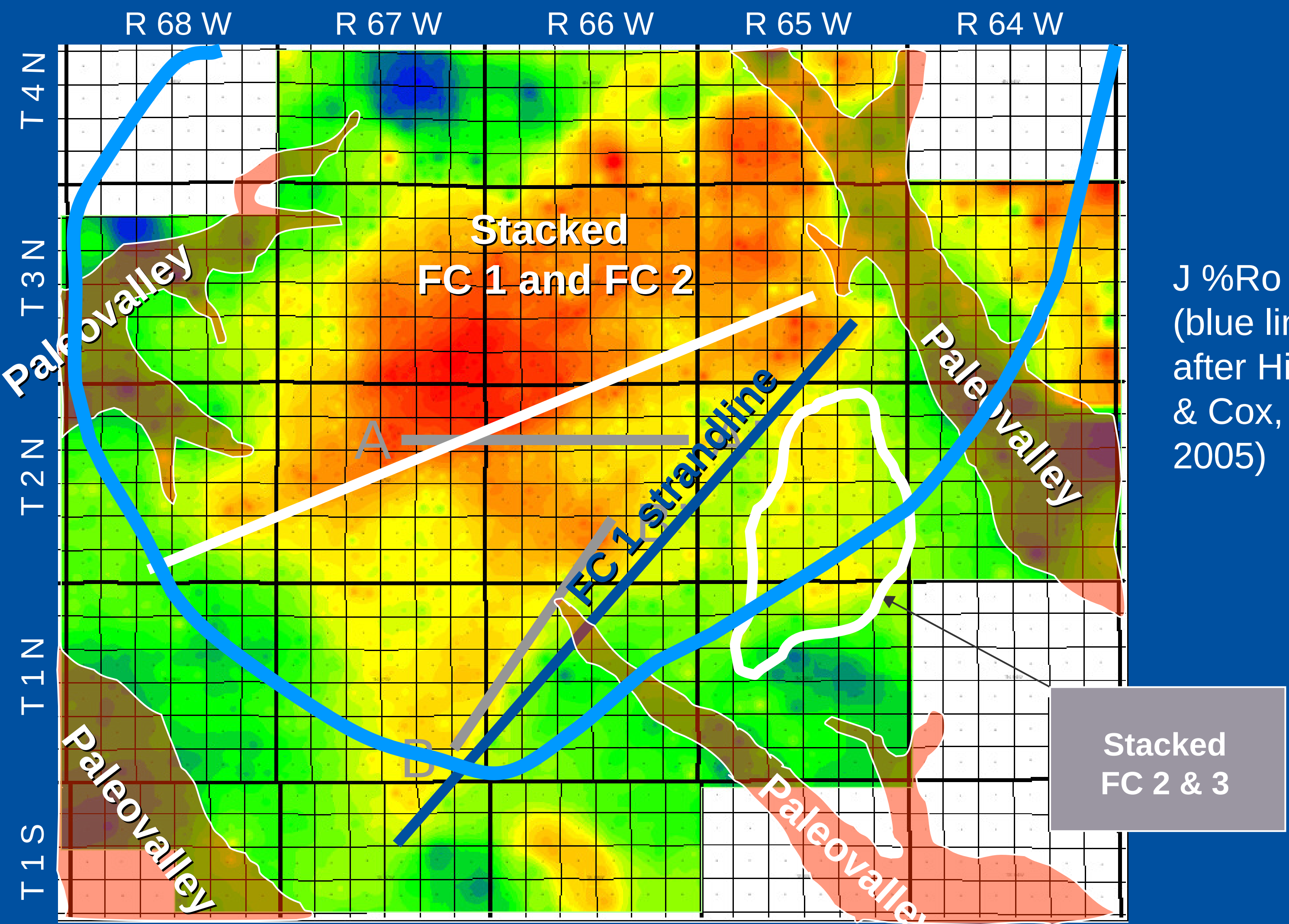
Kugel 21-18

Horsetooth Valley Cross Section



Gustason and Sonnenberg, 2003

J Gas Trap Is Stratigraphic (Facies Pinch-out & Muddy Valley-fill)



J %Ro > 1 (blue line after Higley & Cox, 2005)

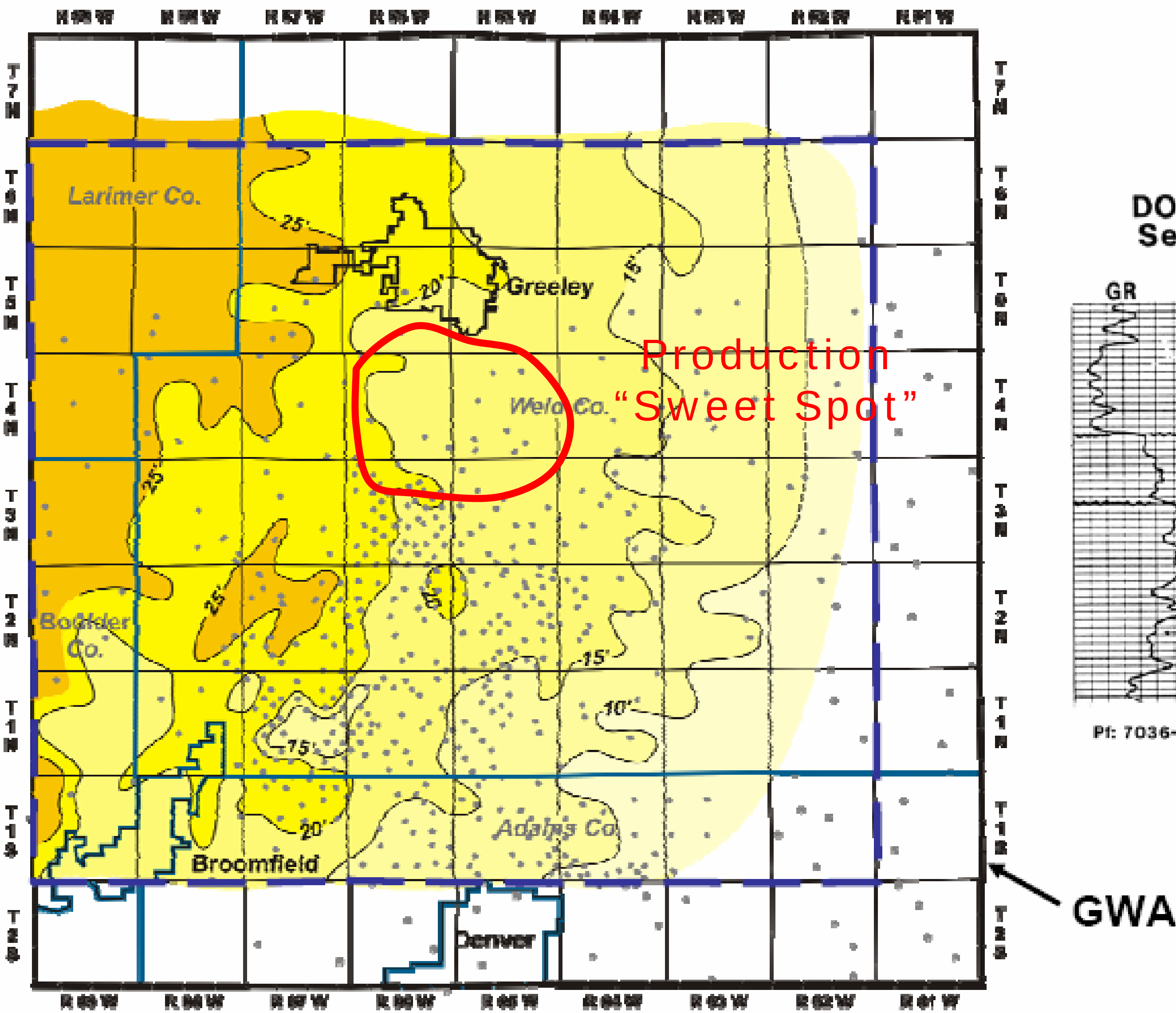
modified from Hu, 2002; Gustason and Sonnenberg, 2003

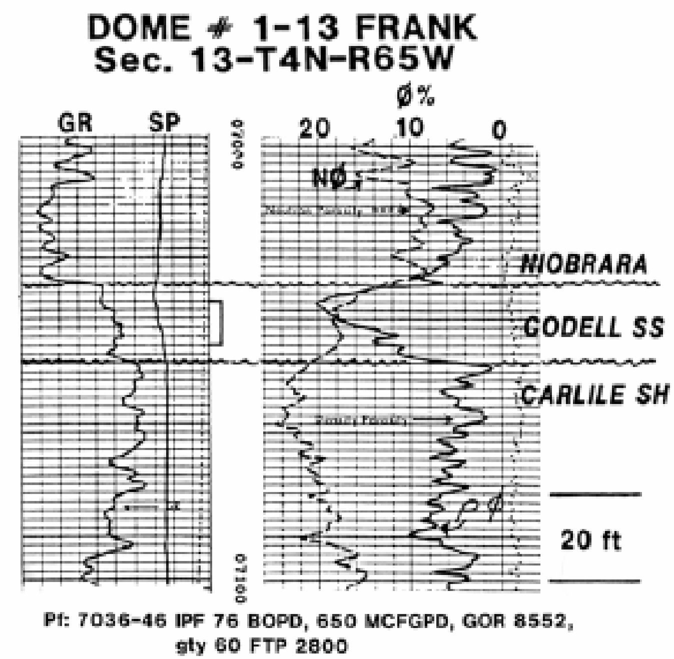
Pertinent Data – Muddy J Sandstone, Wattenberg Field

• Depth	7,600 – 8,400 ft
• BHT, ºF	260
• BHP, psig	2,900
• Gross sand, ft	50 to 100
• Net pay, ft	10 to 50
• Porosity, %	8 to 12
• Permeability, md	0.05 – 0.005
• Original spacing	320
• Est. original reserves	1.3 TCF
• Current Est. Cum	1.3 TCF

modified from Matuszczak, 1976

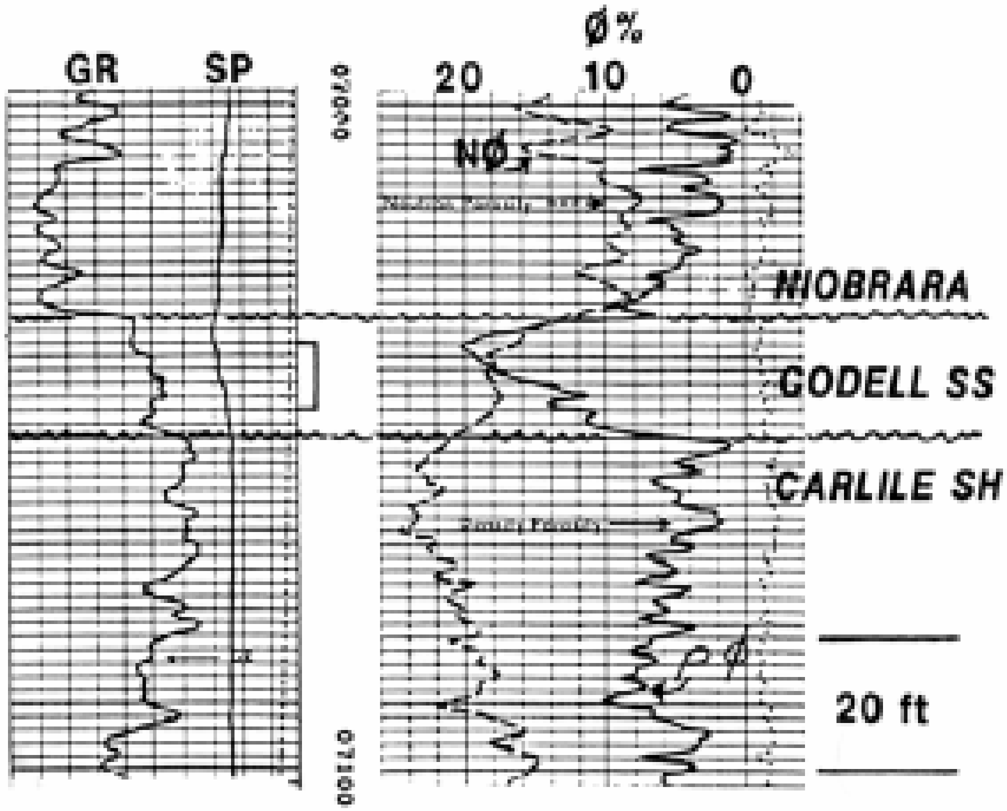
Codell Sand





H. Panigoro, 1988

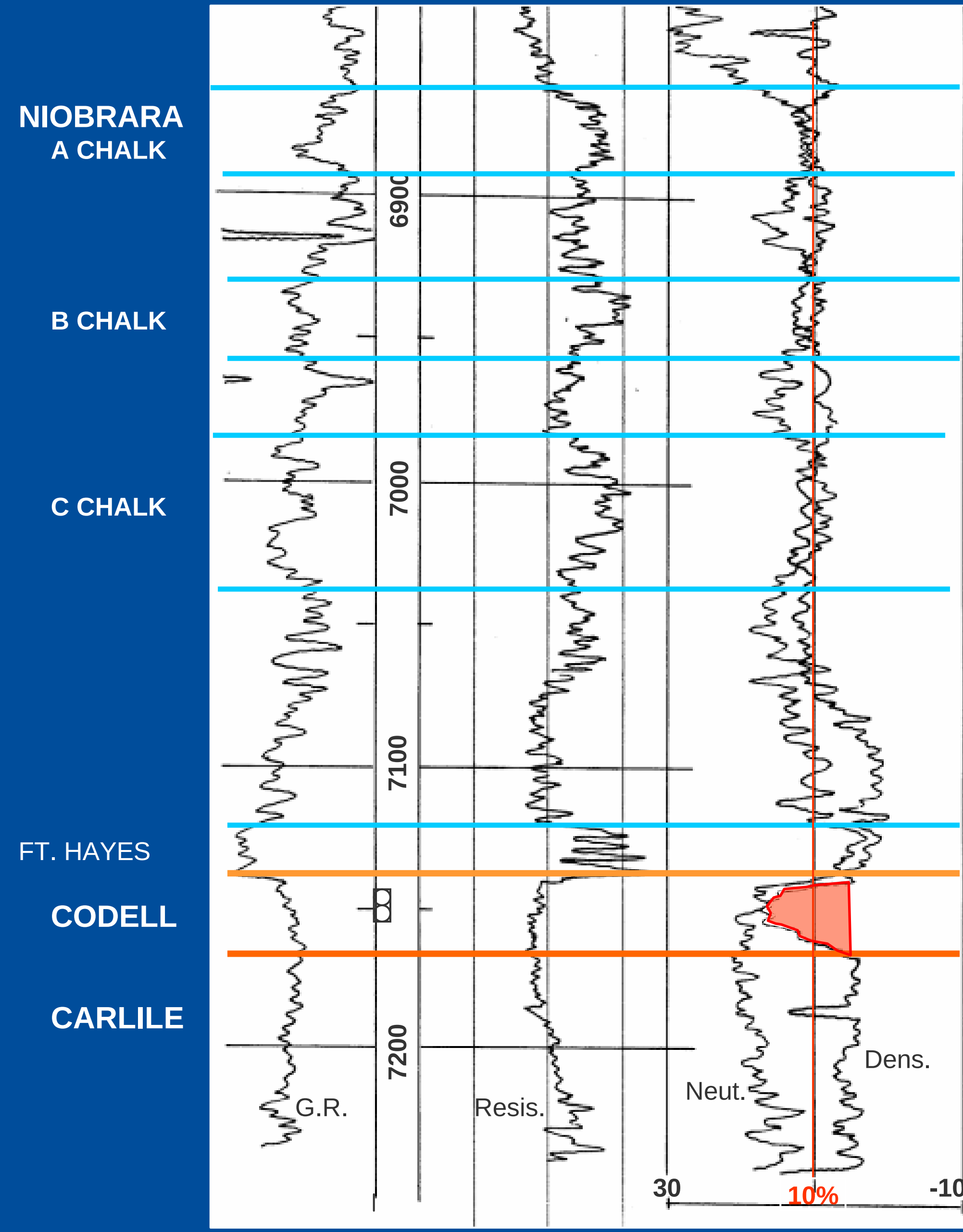
Dome # 1-13 Frank
Sec. 13-T4N-R65W



Pf: 7036-46 IPF 76 BOPD, 650 MCFGPD, GOR 8552,
gty 60 FTP 2800

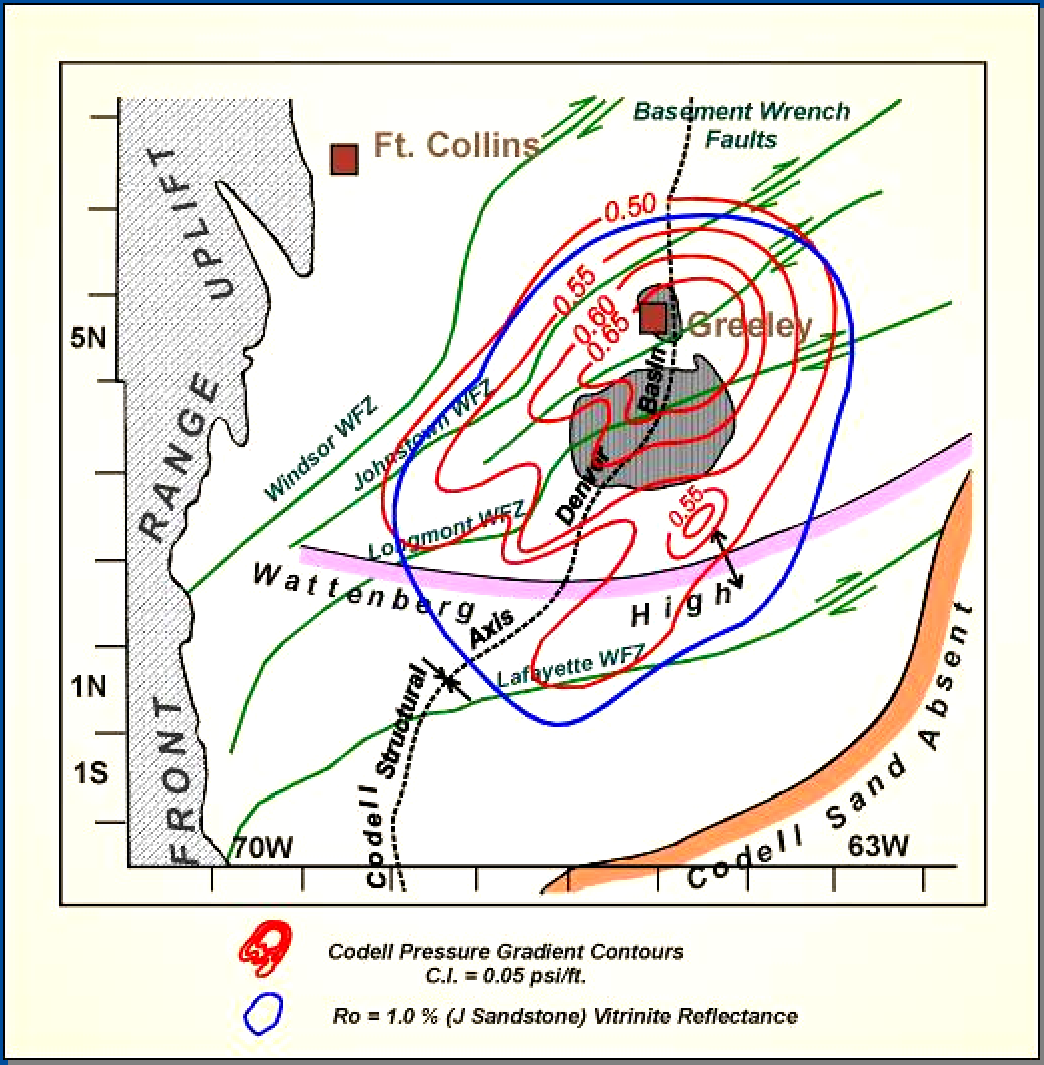
Niobrara & Codell Type Log

NW SE NW
Sec. 8, T3N-R67W



Gustason and Sonnenberg, 2003

Codell Pressure Gradient



- •Based upon P-buildups
- •Range: 0.366-0.669 psi/ft.
- •Coincident with basin axis
- •Most north of “Wattenberg High”
- •Follows J Ro =1% outline (blue)
- •High GOR, sweet spot (gray area) coincident with temperature anomaly

Birmingham, 2000

Pertinent Data – Codell Sandstone, Wattenberg Field

Depth	7,100 – 7,300 ft
BHT, ºF	220
BHP, psig	4,600
Gross sand, ft	10-15
Net pay, ft	5-12
Porosity, %	8 to 12
Permeability, md	0.05 – 0.005
Original spacing	80
Est. original reserves	NA

Lessons Learned

- Bypassed pay
- Technology
- Field growth
- Long range migration
- Reservoir compartmentalization
- LRLC pays
- Geothermal anomalies